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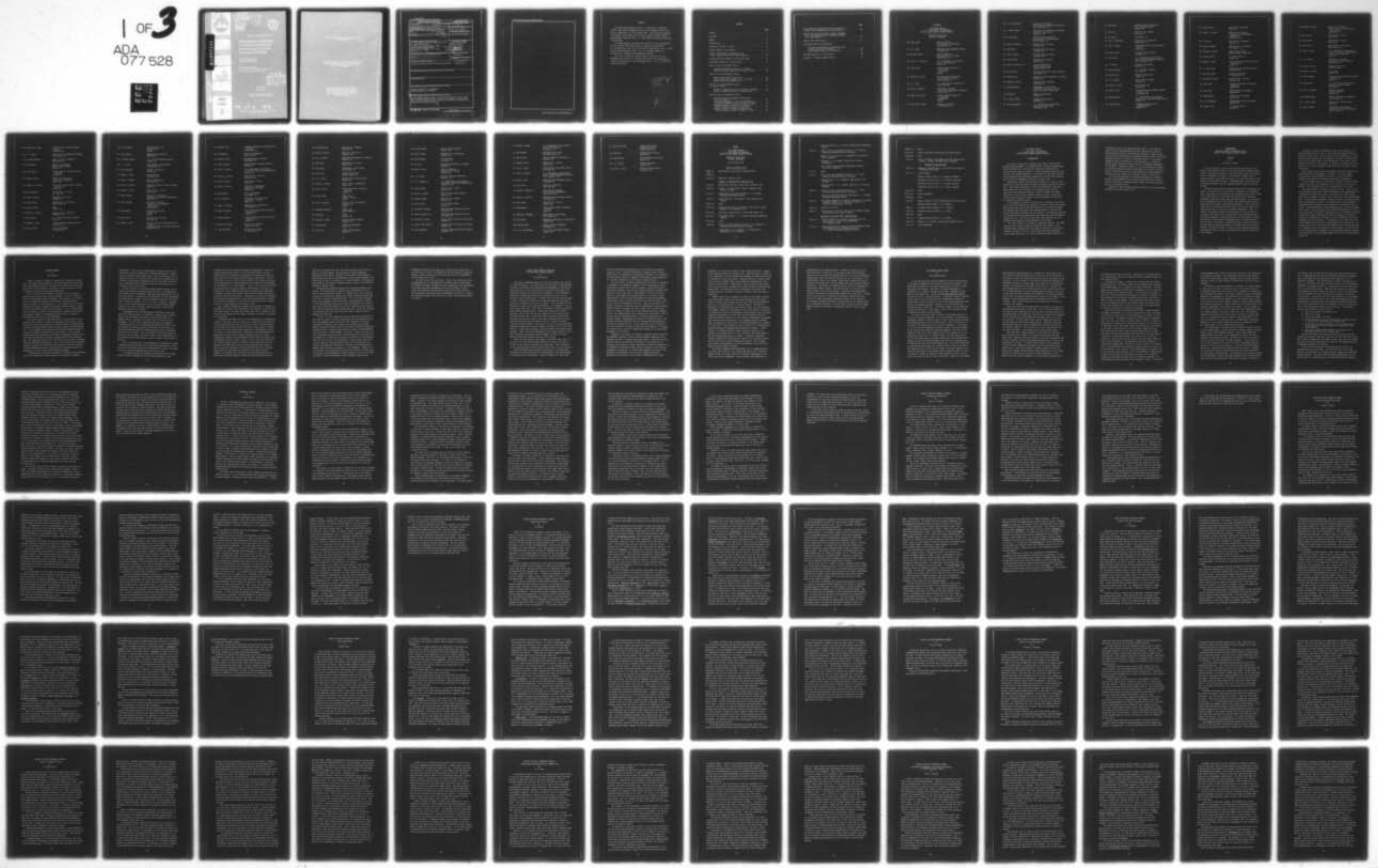

LEVEL II

MISCELLANEOUS PAPER A-79-7

PROCEEDINGS, RESEARCH PLANNING CONFERENCE ON THE AQUATIC PLANT CONTROL PROGRAM

16-19 October 1978
Seattle, Washington

Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

October 1979

Final Report

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

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The 13th Annual Meeting of the U. S. Army Corps of Engineers Aquatic Plant Control Research Program was held in Seattle, Washington, on 16-19 October 1978, to review current research activities and to afford an opportunity for presentation of operational needs.

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PREFACE

The 13th Annual Meeting of the U. S. Army Corps of Engineers Aquatic Plant Control Program was held at the Washington Plaza Hotel, Seattle, Washington, on 16-19 October 1978. The meeting was organized by personnel of the Aquatic Plant Control Research Program (APCRP), Environmental Laboratory (EL), U. S. Army Engineer Waterways Experiment Station (WES).

The organizational activities were carried out and presentations by WES personnel were prepared under the general supervision of Dr. John Harrison, Chief, EL, and the direct supervision of Mr. J. Lewis Decell, Program Manager, APCRP. Mr. W. N. Rushing, APCRP, was responsible for planning and chairing the meeting.

COL John L. Cannon, CE, and COL Nelson P. Conover, CE, were Commanders and Directors of the WES at the time of this meeting and during the preparation of the proceedings report. Mr. F. R. Brown was Technical Director.

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AGENDA

13th ANNUAL MEETING
U. S. ARMY CORPS OF ENGINEERS
AQUATIC PLANT CONTROL RESEARCH PROGRAM

Washington Plaza Hotel
Seattle, Washington

16-19 October 1978

<u>Monday, 16 October 1978</u>

10:00 a.m. to 6:00 p.m.	Registration - South Foyer, Ballroom Level
6:30 p.m.	Reception - High Bay Lobby

<u>Tuesday, 17 October 1978 - Westlake Room</u>

8:30 a.m.	Registration Continues, South Foyer, Ballroom Level
9:00 a.m.	Welcome - COL John Poteat, District Engineer, USAE District, Seattle
9:15 a.m.	Announcements and General Remarks - W. N. Rushing, Waterways Experiment Station
9:20 a.m.	Keynote Address - John Spencer, State Department of Ecology
10:00 a.m.	Break
10:15 a.m.	Aquatic Plant Control in Relation to the Corps' Overall Mission - H. R. Hamilton, OCE
10:30 a.m.	OCE Research Needs System - LTC William Toskey, OCE
10:45 a.m.	Technology Transfer - J. L. Decell, Waterways Experiment Station
11:30 a.m.	Lunch
1:00 p.m.	State of the Art--Chemical Control - D. R. Sanders, Sr., Waterways Experiment Station, Chairman
	Conventional - K. K. Steward, U. S. Department of Agriculture, Fort Lauderdale

	Controlled-Release - F. W. Harris, Wright State University, Dayton
1:30 p.m.	State of the Art--Biological Control - R. F. Theriot, Waterways Experiment Station, Chairman
	Insects - T. D. Center, U. S. Department of Agriculture, Fort Lauderdale
	Pathogens - T. E. Freeman, University of Florida, Gainesville
	Fish - Robert Lazor, Florida Department of Natural Resources, Tallahassee
2:15 p.m.	Break
2:30 p.m.	State of the Art--Mechanical Control - P. A. Smith, Waterways Experiment Station, Chairman
	Floating Plants - W. E. Thompson, USAE District, New Orleans
	Submersed Plants - R. G. Koegel, University of Wisconsin, Madison
3:00 p.m.	State of the Art--Integrated Control - E. E. Addor, Waterways Experiment Station, Chairman
	Chemical-Biological-Mechanical Combinations - E. E. Addor, Waterways Experiment Station
3:30 p.m.	Operational Management of Eurasian Watermilfoil in British Columbia, Canada - P. R. Newroth and Staff, B. C. Ministry of Environment, Victoria
4:30 p.m.	Adjourn for the day
6:00 p.m.	Board buses to Pier 56 for boat trip to Tullicum Village and Northwest style salmon barbeque

<u>Wednesday, 18 October 1978 - Westlake Room</u>

9:00 a.m.	General Session--Corps Element Responsibilities and Jurisdiction in Aquatic Plant Management - H. R. Hamilton, OCE
9:30 a.m.	Expectations from the Research Program, Management Plans, and Implementation of Management Program - J. L. Decell, Waterways Experiment Station

10:00 a.m.	Break
10:15 a.m.	General Discussion and Question and Answer Session
12:00 Noon	Lunch
1:15 p.m.	Corps of Engineers Civil Works FY 80 R&D Program Review - Robert F. Jackson, OCE R&D Office, Presiding

<u>Thursday, 19 October 1978</u>

9:00 a.m.	Assemble in Westlake Room - Instructions and Charges to Technology Area Groups
9:15 a.m.	Groups Assemble
	Chemical Control Group - D. R. Sanders, Chairman
	Biological Control Group - R. F. Theriot, Chairman
	Mechanical Control Group - P. A. Smith, Chairman
	Integrated Control Group - E. E. Addor, Chairman
10:15 a.m.	Break
10:30 a.m.	Groups Reassemble
12:00 Noon	Lunch
1:30 p.m.	General Session - Group Chairmen Reports and Discussions
	Chemical Control Report - D. R. Sanders
2:00 p.m.	Biological Control Report - R. F. Theriot
2:30 p.m.	Mechanical Control Report - P. A. Smith
3:00 p.m.	Break
3:15 p.m.	Integrated Control Report - E. E. Addor
3:45 p.m.	Wrap-up - J. L. Decell, Waterways Experiment Station
4:15 p.m.	Final Adjournment

13th ANNUAL MEETING
U. S. ARMY CORPS OF ENGINEERS
AQUATIC PLANT CONTROL RESEARCH PROGRAM

INTRODUCTION

As a part of the Corps of Engineers (CE) Aquatic Plant Control Research Program (APCRP), it is required that a research planning meeting be held each year to provide for professional presentation of current research projects, review of current operations activities, and review of new research proposals. The contents of this report include the presentations and discussions conducted at the 13th Annual Meeting held in Seattle, Washington, during 16-19 October 1978.

Historically, these annual meetings consisted of a series of presentations of technical papers on research conducted during the previous year. While these presentations proved very informative, there was a lack of desirable open exchange, on a discussion level, between researchers and operations personnel. Such an exchange was deemed necessary in order to define mission problems in such a context that future research objectives could be clearly identified and related to the operational elements' needs.

In an attempt to provide a forum for such an exchange, the format of the 13th Annual Meeting was designed as a series of panel discussions. These panels were staffed with both operations and research personnel who discussed both operational and research aspects of aquatic plant control and fielded questions from the audience. The entire proceedings were recorded and the resulting tapes were transcribed into 288 pages of typewritten text. The text was then edited and condensed into this document which comprises the proceedings of the meeting.

The first priority of the APCRP is technology transfer. The APCRP addresses four specific sectors in effecting this transfer. Each research effort conducted under the APCRP is required to report their technical findings to the U. S. Army Engineer Waterways Experiment Station (WES) each year in the form of quarterly progress reports, an

in-progress review, and a final technical report. Each technical report is given wide distribution of over 350 copies as a means of transferring technology to the technical community. Timely results are periodically published and distributed through an APCRP Information Exchange Bulletin as a means of technology transfer to the general community, with a distribution of over 1000 copies. In addition, general public-oriented brochures, movies, and speaking engagements are available. Technology transfer to the field operations elements is effected through the conduct of demonstration projects in various District Office problem areas. Field manuals are being assembled to serve as the final product of technology transfer to this sector.

The printed proceedings of the annual meetings are intended to provide Corps management with an annual summary and guide to ensure that the research is continually being focused on current operational needs on a nationwide scale.

Appendix A contains summary progress reports of the research being conducted by contracts during FY 78.

PROCEEDINGS

RESEARCH PLANNING CONFERENCE ON THE
AQUATIC PLANT CONTROL RESEARCH PROGRAM

WELCOME

by

COL John A. Poteat

It's our pleasure to host the 1978 national conference for the Aquatic Plant Control Program. As you are well aware, Eurasian watermilfoil, waterhyacinth, hydrilla, and other aquatic plants are choking some of the Nation's waterways. To our Nation's commerce this is serious business, since about one sixth of all intercity cargo in this country is transported by water. Troublesome aquatic plants also are blocking recreational uses and impacting commercial and recreational fishing.

Eurasian watermilfoil has invaded several areas of Washington and Canada. It did this in the early 1970's, although not to the degree that's been found in some portions of the southern United States. Some of the lakes affected in and around the Seattle area include Lake Washington, Lake Union, Green Lake, and Lake Meridian. In the eastern part of Washington, across the Cascades, some affected lakes include Banks Lake, the Sunlakes, and Evergreen Reservoir. I don't think that anybody has all of the answers about what to do with the threat from these aquatic weeds, in our case, Eurasian watermilfoil. There is, however, a substantial amount of information that indicates that we can expect some rather serious impacts from this weed--impacts upon recreation, swimming, recreational boating, and waterskiing; even over in Union Bay the University of Washington crew is having difficulty with the weed. For commerce, watermilfoil poses a potential threat to the hydroelectric generating system to the degree that it would clog intakes. The weed also poses a threat to water transportation and an environmental threat in that it has adverse effects upon fishing and fish spawning.

Therefore, we have an obligation to look at the problem, to try to get as many facts as we can, to try to base our decisions upon an analysis of these facts, to try to arrive at some consensus as to just what the adverse impacts are, and then what we ought to do about them. I get a little nervous when, from some quarters, I get advice that we shouldn't even look at the problem. In the face of evidence that it is serious, I'm a little reluctant to take advice that we ought to ignore the problem.

Upon request of the State of Washington, the Seattle District has been working with the Department of Ecology of the State, METRO (Seattle-King County Government), and WES on a study to develop a program for the control of Eurasian watermilfoil in Washington.

We are looking forward to this week's conference to define future research needs and to be brought up to date on WES's current control methods. This conference will be an invaluable aid to our study.

Our study should be completed in one year (FY 80). After it has been reviewed and approved by higher headquarters, the implementation of a maintenance program could follow. The state as the local sponsor would bear or arrange for others to bear 30 percent of the implementation cost. And the Federal Government, through the Corps of Engineers, would carry the remaining 70 percent. Many major aquatic plant management programs have been instituted after problems have reached the point of crisis: blocked navigation, closed swimming beaches, curtailed fishing, and so forth. Since the aquatic plant problem in Washington is still in its early stages, I believe in some respects we are fortunate in getting a head start. Early prevention and control programs are the keys to reducing or eliminating the problem, not only in Washington State, but throughout the entire country. To oversimplify here, the way we see it at the moment on the west side of the Cascades in the Seattle area, our problem is more one of correcting the problem after it has gotten started: eliminate it and then prevent it from recurring. On the east side of the Cascades there is somewhat of an elimination problem but largely the study takes a little different emphasis, and that is monitoring and prevention.

KEYNOTE ADDRESS

by

John Spencer

I want to preface my remarks by saying that I'm going to be speaking to you from a local perspective, and I hope that my views will help you in understanding the kind of approach and problems that we have and why we look to this conference to provide us with a great deal of help in solving our problem with Eurasian watermilfoil.

Prior to 1975 the word "milfoil" was rarely used in the public media and discussions between resource managers. It was no doubt discussed at length among aquatic biologists. Now, however, it is freely used in the news media without the parenthetical definition that usually followed it in the beginning. It is a concern that's discussed frequently by resource managers, boat owners, lakefront owners, sportsmen, and environmental groups and organizations. It's an aquatic plant which is causing a problem in our own backyard. Within a few blocks of here research workers are struggling with the control of Eurasian watermilfoil in Union Bay of Lake Washington.

This aquatic plant has been identified as a serious threat to traditional uses of many of our lakes and waterways over the past 5 years. During this time we have witnessed its spread through the Okanagan chain of lakes, the Columbia Basin project, and many lakes in western Washington. In the Okanagan, we are working with British Columbia officials to control the spread of watermilfoil in Lake Oscuius. In the Columbia Basin we have been working with the Bureau of Reclamation because it has been found in Banks Lake, the major storage reservoir there; Billycap Lake, the regulating reservoir that goes down into the project; Evergreen Lake; and then Scrutiny Reservoir. Any of you associated with irrigation projects will know the problem that this can pose in terms of interfering with pumping plant intake structures and the general operation and maintenance of canal delivery and distribution systems.

In King County, a restoration analysis is under way in Lake Meridian, and we have identified 10 other lakes with the problem of Eurasian

watermilfoil. North of here, Watcom Lake in Watcom County has been discovered to have an infestation of Eurasian watermilfoil. Watcom Lake is a municipal water supply source. With our knowledge, and I'm speaking of those of us that have been working on the problem here in the state, what Eurasian watermilfoil does to water bodies and how it can be controlled causes citizens to fear that the success in controlling it may be very limited.

We have seen how it can make recreation beaches useless, how it hinders and sometimes prohibits boating, and how it can dramatically alter shallow water environments, sometimes destroying habitats of fish and other wildlife. Coupled with this observation, we have experienced the frustration of trying to control watermilfoil where it now exists and to prevent its spread. It is, in a sense, a predator, a predator that is out of balance thriving on one of the most valuable natural resources that we use and enjoy, particularly here in the Pacific Northwest, and that is our lakes.

In Washington there are approximately 7,800 lakes, ponds, and reservoirs providing water for irrigation, drinking, power, wildlife habitat, and recreational activities. These lakes provide over a thousand miles of shoreline and 177,000 acres of surface water in Washington. In 1975, it was estimated that people participated 11,800,000 times per year in water-based recreation activities; this is estimated to increase by about 42 percent by the year 2000. In addition, people participated 7,900,000 times per year in land-based activities next to lakes. This is projected to increase by about 44 percent by the year 2000. Obviously a loss of this environment due to uncontrolled aquatic plant growth can touch on nearly every citizen in our state.

Also, in one small area in Lake Washington, the problem has raised a tremendous political debate over who has the responsibility to take control of the problem, who has the responsibility to fund it, and what is the best control technology that could be put to use.

It is significant that the meeting is being held here in Seattle because we have an opportunity in the Pacific Northwest to take

preventative action to control the spread of watermilfoil. This is an unusual situation which seems to occur only where there's an early recognition of the problem, the techniques for preventative action are known, and there is a willing political basis to take action. Here in this state, as early as 1975, we were notified of the problem occurring in the Okanagan area of British Columbia by the Ministry of Environment, and specifically by Dr. Peter Newroth. Early in 1976, Governor Dan Evans met with officials of British Columbia, became aware of the threat of watermilfoil to the Columbia River system, and directed the Department of Ecology to become involved and to begin working towards some kind of program to deal with this problem. Subsequently, the State of Washington has accepted the responsibility as the local sponsoring agency required by the Federal Government for the Corps to become involved on a funding basis of 70 percent Federal and 30 percent local.

Most recently, Governor Ray, through our Department of Ecology, has directed us to become a state committed to this program, to proceed with the research that is now under way in Union Bay, and to continue to work with local governments and the Federal Government to seek out a solution to this problem.

Although we have what seems to be the ingredients of a preventative program, I feel that I have to caution you, perhaps not the researchers or the applied scientists that are here, but I have to caution those of you that have just become involved in this as I have, that it is doubtful that we can look towards total eradication of watermilfoil where it now exists. We look towards this conference and the organizations and people here to point the way towards reasonable levels of control balancing the economic and environmental benefits with the economic and environmental costs of control. Again, I have to note that while we've just become involved in this, the political controversy has very much focused on "to what extent can you control this particular problem, what are the best techniques, and how acceptable are they to the many groups that'll be involved or be affected by any kind of control program." The aquatic plant researcher and the applied scientist are being asked to provide answers to some very tough questions, such as,

"What are the effects of 2,4-D? How, when, and where can it best be used in a control program? How effective are other techniques, mechanical and biological? And what are the possible environmental modifications that can be used successfully such as lake drawdown or the restriction of light by screening in a control program?" The answers to these questions and others are needed to mount a control and prevention program for aquatic plants.

Providing these answers challenges our existing government institutions. The problem posed by aquatic plant proliferation does not wait for the processing of permits. It provides only a short time for research to provide better answers and it poses financial problems that do not fit our current institutions well. All of us should recognize that we are standing in between the need to take action now, the need to take environmentally safe action, and the possibility that unless we take action now we will either be too late or people will take control into their own hands and do more damage than good. We are all operating in a situation that has a short fuse, and time is without a doubt a commodity we lack most.

I think it is very significant that this meeting is being held at this time and I know it's only a coincidence that it happened this way, but I was reminded coming up here that this conference is entitled "Planning for Research," and I think it was yesterday that Herbert Simon was awarded the Nobel Prize for his work in economics dating back perhaps 20 years, in which he dealt with the problem of decisionmaking and the behavior of decisionmakers. The point, I think that all of you know, that Simon has dealt with is that decisions have to be made in an environment, in a situation in which we do not have all the information that we'd like to have. This conference, I think, should take note of the fact that this award was made and that you're dealing with the subject of planning for research at a time when we're dealing with a subject where the people are asking us to do something. Perhaps it'll be related to you in more detail later but we did have an incident here in Union Bay of Lake Washington in which someone took action into their own hands to control watermilfoil while Government agencies were

struggling with what was the best way to control this problem, how is the best way to do this. So, believe me, you are faced with aiding and helping us make a decision when we do not have all of the information that we would like to have.

The opportunity to be successful, I think, is at hand, and we have the experience and the knowledge about possible control technologies. Our Federal Government, through the Corps of Engineers, has the authority to aid State and local government to solve this problem. We look toward this conference and the work now under way to help State and local governments develop the proper organization to carry out a control and prevention program, and, above all, to select the preferred methods of control.

AQUATIC PLANT CONTROL IN RELATION
TO THE CORPS' OVERALL MISSION

by

H. Roger Hamilton

The Corps of Engineers today is in the water business and has been for nearly 200 years. It's often difficult for people to understand why the Corps is involved in the development and management of the Nation's water resources. In the early days of our country's development, the waterways, streams, and rivers served as highways. As the settlements along these streams and rivers grew into towns and cities, the importance of water likewise grew. Adequate levels of water were necessary to ensure navigation of vessels that transported material and goods up and down the rivers from one place to another. Water was needed for the production of power for the home and industry, for irrigation of crops, and for many other uses. Water level also became a problem at times and flood control became necessary. These tasks required the talents of engineers, and at that time the only engineers in the country were in the United States Army. As the Nation grew, Americans acquired more disposable income, more leisure time, better transportation, and other amenities identified with an affluent society. Outdoor recreation activities became important in the use of the water resource development. Congress recognized this with the passage of Section 4 of the 1944 Flood Control Act which made recreation, fish, and wildlife authorized project purposes. Today, the Corps of Engineers is the largest supplier of outdoor recreation opportunities and the managers of some of the most important and unique natural resources in the country.

While the total land of Corps lakes is relatively small (about 1.5 percent of the total Federal land available for outdoor recreation), the use of that land for recreation is rather high. About 25 percent of all recreation that occurs on Federal lands occurs on Corps projects.

Water has always been important and necessary to the successful development of any society and to the maintenance of the high standards of that society once established. America's demands for clean water

free of obstructions and pollutants for a wide variety of purposes continue to grow. Excessive populations of aquatic plants in water bodies result in hinderances to navigation, detriments to the operation of flood control projects, clogging of hydroelectric power generators, and a general degeneration of the aquatic ecosystem itself.

One activity that is almost synonymous with the Corps of Engineers is dredging of the navigation channels. We're responsible for maintaining about 22,000 miles of inland waterways, about 3,000 miles of intercoastal channels, about 219 lock and dam complexes, and about 500 small boat harbors that serve a large number of recreation users in addition to the commercial shipping interests. So we have a rather large program in water resource development and operation management. In addition to that, let me add that there are about 434 lakes in this country, built and operated by the Corps. Nearly one fourth of our Nation's ton-miles of intercity cargo is transported on these waterways, chiefly because the average cost per ton-mile, which is about three tenths of a penny, is lower than for any competitive mode of transportation. And, significantly, water transport uses less energy. There's no doubt that the navigation system is extremely important in the American economy. Approximately 50 percent or 579,000,000 tons of the domestic waterborne tonnage in 1977 was energy-producing commodities, principally petroleum and oil. Grain constituted about 21 percent of the total, and about 12 percent of the total was chemicals. Of course, the remainder was a variety of commodities essential to the growth and maintenance of our Nation.

Dredging is, of course, the removal of sediment from the bottom of the navigation channel in order to provide adequate clearance to accommodate the draft of vessels using that channel. Aside from the side effects created by accumulation of sediments on the bottom of our waterways, the presence of massive quantitites of aquatic vegetation, on or throughout the waterway column, obviously presents a very definite impediment to navigation. It has not been uncommon in the past to see situations where waterways are completely clogged and blocked, impassible to boat traffic, due to jams of waterhyacinths or other

vegetation. We can still see some of that in some areas today. Aquatic plants contain as much as 95 percent water. When this water is locked up in the vegetation, it's not available for domestic or industrial use such as irrigation or any other purpose. Enormous densities of aquatic vegetation occupy a valuable space in the reservoirs constructed for the purpose of flood control. Additionally, they can preempt proper operation of these projects by jamming outlet works severely restricting downstream flows. The resultant effect is flooding up in the pool and increased peril to the dam and structure as well as lives and property downstream.

Aquatic plant control problems are caused by some domestic species and by many exotic species that have been introduced in this country either by design or by accident and have found ideal growing conditions with few or no limiting factors or natural enemies. The Corps of Engineers, in cooperation with other Federal, State, and local agencies; the academic community; professionals in the private sector; and others, is attempting to discover and implement control measures that will manage vegetation populations at a level that will not interfere with the authorized functions relative to water resource, development, and management for which we are responsible. We're administering this program under the authority of Section 302, The Rivers and Harbors Act, approved 27 October 1965. That provides our basic authority for a comprehensive program consisting of planning control operations research. Our objective is to develop effective control tools as a result of our research, for implementation in a safe, effective, and timely manner to get this program going and keep it going. Through our technology transfer program we're doing that now. When we say technology transfer we don't mean just to Corps Divisions and Districts, we're talking about people in universities, in the State agencies, and all the non-Federal and other Federal agencies.

The Chief of Engineers has established a set of command goals for the Corps, and I'd like to just briefly read them to you. They are: support of the total Army, support to the public, development of the Corps' work force, management of Corps resources, and fulfillment of

requirements for the quality product. I think it's important to note that these goals as they apply to the Aquatic Plant Control Program, either directly or indirectly, support all five of the Corps of Engineers command goals, which the Chief has declared for our total mission. The advances made to date in the Aquatic Plant Control Program track quite favorably with these goals. We have managed our rather limited resources effectively. We continue to develop the Corps' work force through our research and control efforts. The American public has received tremendous support with a quality product. Indirectly, the professional excellence associated with this program supports the total Army. I would like to leave you with a challenge to continue to improve upon that record by a timely turnaround, technology transfer of the results of our research to operating elements, and identification of research needs by the operational personnel. In this manner, we will be able to manage aquatic growth in the interest of meeting our Nation's water resource needs.

OCE RESEARCH NEEDS SYSTEM

by

LTC William Toskey

I will talk about the research program in the Civil Works portion of the Corps of Engineers as it relates to Civil Works directly. You might want to know why I am up here talking about it and who I am and why should I be involved. The Office of Staffing Management is responsible for a couple of things; by the title, management of manpower is our biggest task. We also publish Water Spectrum magazine. We think that it is a fine publication. It has won a couple of national awards and if any of you have read Brent Blackwelder's articles in recent issues, you'll see that it is not a self-serving publication and, in fact, it probably is going to destroy us if we don't watch our editorial policy a little bit. I am serious though, we are looking for interesting articles in a wide range of water areas and aquatic plant problems are certainly in that category.

The task of our office that I am going to talk about today is in the area of research monitoring. We try to coordinate the Research and Development Program in terms of policy so that the Civil Works policies are implemented also into our research effort. This is not easy to do in terms of the things that we are trying to emphasize. For instance, if you are trying to emphasize recreation in terms of the total budget in the way that you operate and allocate manpower in one part of your program and then over in the research side of your program you are not putting any money into it, it doesn't track. The same way exists on all the other wide range of problems; therefore, we are responsible for making sure that the research program tracks with the long-range goals of where we want the Civil Works Program to go. We are also responsible for developing some systems, one of which I want to talk to you about. The biggest reason, in fact the only reason, we get any interest at all from the other people at the Office, Chief of Engineers (OCE), is that we control the money; it has got to come through our office. We may not be very big, but the fact that we have got to sign off on the budget

makes people at least listen to us. Lastly, and I would like to get this across to the Corps people that are here, we are the interface, in my opinion, between the Field Offices and the rest of the Corps, and the OCE staff. We are the voice of the District and Division Engineers in Washington in terms of trying to make their needs felt in the research program. No disrespect to the people of WES, but it is possible for some research people to get carried away with their own interests and we try to bring them back on track by manipulating the budget a little bit to make sure that field interests are included in the research program. This is what is called the Research Needs System, and the "Needs" is the emphasis. We are talking about what a field needs in the way of research. That is why we developed the system and that is why we are involved in the program.

About three years ago OCE reorganized a few aspects of things and some problems were evident at that time. A lot of the Field Offices at the Districts were reporting that the labs were not doing anything that was helping them or it seemed that they were not getting any information or were not quite sure that anybody was listening, just a lot of that type of input. The labs would counter that by saying that they were not sure what the Field Offices really wanted. Therefore, we had the feeling that there was a lack of communication between the field and the research community. The output was not in the right format or in the right time frame. I will mention more on this problem later.

There was also a tendency--again, I do not think the labs will agree with this, but I think if you looked at the budget you would agree--that a number of work units seemed to never get finished and that the more research, the more requirements generated, and so on until you never seemed to finish. Of course, everyone had the same complaint, "We did not have enough money or people to do all the things that we wanted to do." There are a number of research programs in the Civil Works area to manage, and the Aquatic Plant Program is just one of many. The list is rather long and each one of these programs has a tech monitor who feels that his program is the most important program that

the Corps has ever done, or will do. Therefore, we are dealing with a lot of prima donnas and we are trying to allocate resources between the wide range of areas.

Concerning the budget, in 1978 we were talking about $26 million Corps-wide for all Civil Works research and development (R&D) programs; for the 1980 budget, we are hoping to get about $30 million. The 1979 budget was not damaged by either House of Congress, so we are expecting the 1979 figure to be fairly accurate. If you go back a few years to about 1975, the $26 million was down around $12 million. Therefore, we have come quite far Corps-wide, and while you will hear more about a lack of funds for this program, I think that Corps-wide overall there has been a significant increase in research money in the recent years. We are still talking about 1 percent of the Corps' Civil Works budget as being in R&D, which is a really low percentage.

What do we do with the Research Needs System? We make estimates and budget requirements; we allocate the money after we get the budget out; and then if there has to be any reallocation in midyear, we use a system for that. The emphasis though is on the budgetary requirements side. That is why we came up with this system. There are a couple of principles of the system that I would like to point out. The first one is that anyone could input ideas, anyone in the Corps and even outside of the Corps if they feel like it, but certainly within the Corps. After they input the ideas, then we ask the Field Offices to assign priorities to these ideas, whether they think that it is a good idea or a bad idea. If some crackpot kicks in an idea, we put it into the system, but then the Field Offices evaluate and decide which ideas are really worth following up. The laboratories are then required to evaluate and estimate what it would cost to do the work on the research idea. OCE then reviews the laboratories program (there are a lot of us at OCE involved in this review). Field representation is requested also at this review to make sure that there is no breakdown in communications, to make sure that what is written down in a page or two of problem statement is translated correctly into the laboratory statement. We then integrate the whole program and put together a budget. The Research

and Development Office (RDO) gets the money and directs the laboratories to proceed with the work. The laboratories execute the work and distribute the final product, which, hopefully, will be usable, directly relating to what the field originally identified in the first item as problems.

The format of a mission problem is as follows. We assign a number at OCE, you do not have to worry about that, but we want the title to be somewhat descriptive, and we want a brief statement of a sentence or two describing the problem. Next comes a follow-up of about a paragraph, sometimes two paragraphs, of the description of the problem, the application, how the Field Office intends to use the solution, and a couple of key words for use in the computer program to extract similar problems and eliminate duplication. I want to point out to the Corps people that planning, engineering, and operation are coequal. A lot of people in the research program and out in the field feel that engineering provides the research program in the Corps; that is not true. We think that planning and operations have just as many, if not more, problems that need to be researched; we want to make sure that their input is felt on an equal basis at the District level. We depend upon the District Engineer to try to develop, within his District, a system that will give equal weight to all of these kinds of problems.

The rating system we developed is based upon four factors that are all given equal weight. The four factors are safety, urgency, potential dollar savings, and intangible benefits. Public image, which was a separate factor last year, is now considered as a part of all four. Weighing is described as follows. Each factor is rated on a scale of 0 to 10; we get a lot rated 0 in some categories. If you weigh each one of those categories a 10, you can see that the maximum weight you can get is 40 out of any one District. The total Corps-wide maximum we had out of 38 Districts was 1200 points this past year. Therefore, you can see that there are some problems that are rather significant in a wide range of organizations. The laboratories use mission problems in the development of their long-range programs--their five-year plans. They look down the road and see if what they are going to research in

the future is tied to what the field feels that their problems really are. I mentioned that we also use the mission problem in the development of the budget and the allocation of the budget after it is approved by Congress. The relevancy part is where we ask them to outline, in a work unit, what this research is relevant to, which mission problems it is directly related to. Ultimately, we like to have a work unit for each mission problem. Right now the labs have not endorsed this program with great enthusiasm as they feel that we are interfering in their business, and they are right, we are trying to interfere in their business. We get some work units that address five or six mission problems and we feel that this is not a good relationship because the study becomes too generalized or some important missions problems may fall by the wayside and are not fully addressed. We like, in the long run, to have one mission problem for one work unit. The objective, again, is the objective of the work unit:

a. What is the research intending to do?

b. Where is it going?

c. How do they intend to do this?

d. Are they going to do this by applied research, model testing, or whatever else the researcher is going to do?

e. Is it going to be done by contract or by an in-house work force? This can be decided based on the laboratory's past accomplishments.

f. What are the physical applications? We at OCE are very interested in this facet of the work unit.

The mission problem comes down from the Field Offices into the program review and the work units come from the Corps labs down through their chain of command into the program review. Then, after the program reviews, we discuss the problem and it goes into the budgetary process and emerges, hopefully, for funding.

We are now in the process of evaluating the work units to be addressed for fiscal year 1980. They first went out to the field. I have one copy back that is a computer printout consisting of about 400 mission problems. Last year we had 800 mission problems and you can see that this is a horrendous task to evaluate 800 different research

problems. Therefore, we narrowed it down to 400 problems this year. Out of that 400 about 160 will be funded during FY 80. The highest ranked mission problem was a structural engineering case. Next came earthquake design. No one area dominated this year. Last year the planning problems tended to dominate the top 10 (there were about five or six planning problems in the top 10). This year it is either structural engineering or earthquake design. Aquatic plant problems did not make the top 10 list; however, an aquatic plant problem did make the top 20. Mechanical control is the highest ranking aquatic plant rated mission problem this past year, ranked between riprap gradation and failure criteria for concrete under earthquake. That was the only problem in the aquatic plant area that got enough points to get included above the cutoff line of 160 out of 800. If a problem got a little over 600 points, then it was included in the fiscal program. The Districts do not agree within priorities between themselves as to which is the most important problem. They were not expected to since the problem is different for each part of the country; New Orleans' problem is different from Jacksonville's problem and certainly different from Seattle's problem. A District would not necessarily assign a score of 40 to the aquatic plant problem as they may have something that they feel is more important, even through this is an important subject. Seattle did give a rather high ranking to a number of problems reflecting things discussed earlier by COL Poteat. The Corps, as a whole, does not rate the aquatic plant problem very highly at this time because the problem is not widespread yet. If you from the Corps want to get any money into this program, you are going to have to express a greater interest through this mechanism to your District Engineer and get him to assign high values to those problems that you really want some research done on.

The listing of high priority projects is used again concerning the budget. We juggle the money around between these programs. Therefore, the funding levels between, for instance, materials and coastal engineering, are not the same now as a year ago. A year ago the numbers would have been a little different in FY 79. We adjusted this year's

budget based upon input from the field. After receiving the input from the field, we take money out of one program and put it into another and so on, making sure that the overall total did not exceed that which was authorized by Congress; thus, the mission problem system was used. In FY 78, the year we just finished, 50 percent of the money was put into research directly related to mission problems. The other 50 percent of the money was put into research to complete the studies that had been ongoing before the Research Needs System started and to attack research that OCE knew was necessary, but the Field Offices had not rated highly. We are hoping to move that 50:50 ratio to about 75:25, 75 percent of the money going to support field needs and 25 percent to reflect long-range goals to ensure continuity of ongoing research projects. For example, as I mentioned, last year the high rating of problems was in the planning area, this year they were more on structural and earth-quakes. Since we cannot balance a research program that fast, we use that 25 percent level to smooth things out.

TECHNOLOGY TRANSFER

by

J. Lewis Decell

Webster's Unabridged Dictionary defines technology as the science of the application of knowledge to practical purposes. It also defines transfer as a carry-over or generalization of learned responses from one type of situation to another. If one refers to a synonym finder in a search for a definition of technology transfer, you will find that transfer is listed as "convey from one place to another" preceding the synonym. However, the word technology is not listed in a synonym finder--at least not in the one I checked. That could lead one to the conclusion that there is no synonym for technology and thus no substitute. However, while I believe that there is no substitute for technology in aquatic plant control, I have to challenge the logic that leads one to that conclusion. For if I apply that logic to the term transfer, then I must, by association, conclude that there is no substitute for the act of transfer itself. I cannot accept this because I believe that technology not applied is a waste, and, in fact, it is difficult for me to imagine that we can generate technology without some resulting application. Sometimes this application is planned and other times it happens in spite of our efforts. It is this latter mode of application that I think tends at times to make us embrace the philosophy that if we develop a technology, the problem will automatically be solved. Although this apparently happens, I think there is a fallacy in it when you apply it as a management practice. That is, that we cannot repeat the process of technology transfer because we do not know exactly the sequence of events that took place in the transfer process because it was accidental. We should realize that any technology transfer is a dynamic act involving both technique and application and our degree of success can only be assessed after the fact.

The point I want to make here is that technology transfer may be in itself a science. It is a continual process that requires and warrants the same intensity of attention as our basic research effort. I suspect

that our most difficult task in solving an aquatic plant problem begins after a technological breakthrough results from our basic research. This is not meant to belittle the research effort by any means, but there is a tendency to think of the technology transfer process as a natural one. It's been my experience so far that it is not. It is no more unplanned than the scientist's technological breakthroughs are unplanned. In basic research the scientist conducts a certain planned sequence of steps designed to test his hypothesis. He will admit, after the fact, that it was sometimes necessary to alter his original course of action because his knowledge was continually increasing. He will not and should not admit that his achievements were the result of some process that just happened. It was the result of a well-thought-out approach and this must also be the case, I believe, in our process of technology transfer.

Having failed in my literary search through Webster, Roget's, and others, I have chosen to formulate my own definition of technology transfer for the purpose of this presentation. I submit that technology transfer is "the continual process of the application of knowledge in a practical form, the net effect of which is the solution to a previously identified problem"; in a sense that's the process that COL Toskey talked about, with a mechanism set up to achieve that within the Corps. It is a fairly simple concept to grasp, but it's not necessarily a simple process to implement in all cases. More often it's very complex, but it's not necessarily complicated and it is a mix of timing, knowledge level, technique, education, and just good old practice. Knowledge level is what we achieve as a result of the research, but technology to be transferred starts the process. I think we're smartest when we realize what we <u>do not</u> know, but yet we have to go forth with the thing that we <u>do</u> know.

That brings us to the element of timing and it's been said, especially in wartime, that half-intelligence before the fact is worth more than full intelligence after the fact. I think that's true in our aquatic plant control research and application. John Spencer said we have to make decisions in an environment in which we still don't have all the

information we'd like to have, so timing then is the essence. Once we achieve a potentially applicable solution it must be applied in a timely manner. Granted, if we study a problem a little more, we will increase our knowledge base. That study should continue in some cases. But we should not preclude the testing of our developed knowledge on a real world problem for the sake of research. Technique is important, how we apply our knowledge at the correct time can dictate the degree of success of the overall outcome, but, beyond the first attempt, technique is a learned skill and, for our processed purposes of aquatic plant control, we have now stepped into the operational arena. During the development of an operational technique, researchers should gain knowledge that will enable them to better focus on their future research on field problems.

The operations personnel, at this point in development, are beginning to learn how to be more efficient at their jobs, which is to control the problem within a given time. Therein lies one of the critical education elements of this process known as technology transfer. Next is practice. Initially, it should begin with specific guidelines on how to conduct operations based on our current knowledge including a predictable level of expected results. During these daily operational practices, additional knowledge or technology is gained for the research as well, and the technology transfer loop closes. It must, or it could not be a continual process.

Of course, the real question that we're here for is what's being done about technology transfer in the Corps' Aquatic Plant Control Research Program. After all, it is the number one priority of the overall Aquatic Plant Control Program. As a result of our attempts to actually place the research knowledge in the user's hands in a practical form, we have realized just how many facets and how complex the technology transfer process can be. I'd like to discuss with you our present perspective of the mechanisms and the products that we presently use and the audience to which these are directed.

First, technology must be transferred to the technical community. The findings of the scientist's effort and/or the results of the research effort must be conveyed to other scientists. The main products

by which we try to accomplish this are our technical reports and miscellaneous papers. At the present time the distribution list for these Aquatic Plant Research Program reports exceeds some 350 addressees. In addition to these reports, technical briefings are periodically held that provide an exchange of information on closely related or coordinated research projects. This type of exchange gives the reseachers an opportunity to directly compare notes at various stages of their research, and this method is more timely than the published text. Field operations personnel must be continually informed of developments that hold promise for potential application. These operations need solutions now because their aquatic plant problem is a present one resulting from two related major factors. First, research has not yet provided operations with tested guidelines for conducting prevention programs. Secondly, operations usually do not report infestations until they become of problem proportions. From the information standpoint, new techniques and procedures can be transmitted through engineering circulars and information bulletins. Eventually, we hope to supply them with field manuals, a cookbook if you will, on exactly how to assess their problem and how to select and implement an optimum control procedure with some predictive element of what they can expect in the way of results. But what about the present? Operations cannot and should not be content to wait for a manual before dealing with their problems. Nor, on the other hand, can they immediately mobilize and begin to conduct control operations just because they're suddenly convinced they have a problem.

Some degree of hands-on experience is valuable for some time before they can become truly operational. We have implemented demonstration projects that we hope serve this purpose to some degree. These projects are partially research in the sense that the needed data and knowledge will be generated, but they're conducted on an operational scale such that hopefully some degree of the problem will be brought under control. Ideally, operations people would be involved with a hands-on effort and thus gain some valuable experience. In order for them to respond properly to both operations and research, Corps management must also receive the proper type technology in a timely manner. They tend to

know our needs, but these must be identified in terms that enable them to divide limited resources among hundreds of programs with the confidence that their decisions will return maximum results for the dollars invested.

In addition to continual requests for information and periodic required work unit documentation and progress reports, we try to use four other methods or documents to convey our message to management.

The first of these is a 5-year research and development plan. This plan serves as a guidance document for the program and is updated as required to reflect new technologies and new program emphasis or direction. The annual Civil Works R&D program review that COL Toskey mentioned is the second method and is used for identifying not only research needs but the user's needs and priorities also. It also places the identified needed research in a priority commensurate with these user's requirements. For the first time, this year's R&D program review is being held in conjunction with this annual review meeting.

The proceedings of each year's meeting comprise the third method. These proceedings are given wide distribution and provide certain management elements with a detailed summary.

The fourth method of technology transfer to management is an executive summary. Within 30 days of the close of this meeting, we will condense inputs provided by researchers and the attendees into an executive summary for the Corps' Chief of Civil Works that will outline our intended next year's direction.

Technology transfer to the general public is also vitally important. The need to solve an aquatic plant problem can almost always be traced to a request initiated by some sector of the general public. These requests are not necessarily in writing or by telephone, and they are often directed to the wrong office or agency. We are charged with a nationwide responsibility and, for the most part, the general public doesn't know we're ready to respond. Why? I believe two things may contribute to this situation. First, the public is not well informed and, second, once we're open for business, we tend to sit back and wait for the rush to the door.

It's our job to inform and educate the public regarding the capabilities to deal with these aquatic plant problems on a daily basis. We attempt to do this by using four basic methods of technology transfer. One of these is a periodic distribution of an information exchange bulletin. Anybody involved in aquatic plant control research or operations, Corps, contractor, or even outsiders, is welcome to submit articles for publication in this document. Although semitechnical, I think it has been proven to be very informative to the layman. Project brochures, the second method, have proven to be one of the most effective technology transfer tools to the public used to date. These are very widely distributed, including sometimes occupying a prominent pigeonhole in a motel lobby.

Public speaking engagements are a third method of keeping the public informed. To date these have ranged from grade school to civic clubs to national briefings.

By the first of January, we will have three short, informative movies completed for loan to interested organizations that will provide us and the District Offices with a fourth effective method. I cannot overstress the benefits of technology transfer to the general public. To be effective, the process must begin very early in the project planning stages.

Believe it or not, the public does have usable inputs that can be incorporated into overall project direction when these are identified very early. There is no reason why they should not be an integral part of the planning process and the project team, but I think at times we have to seek out their help. After all, it's not only their problem, but it's their money.

In summary, let me say that I am becoming more and more convinced that increasing our effectiveness in technology transfer will be the major contributing factor to whatever success at problem solving we may enjoy during the next few years. This is not to say that we do not need new breakthroughs--we do, and I am confident that we now have a proven ability to develop and apply technology and solve aquatic plant

problems. For those of us in our business who are not so technically skilled as to make a major research contribution, we have the responsibility to stay alert and match research results to the operational need in a timely and usable manner. We owe it not only to the people with the problem but to the researchers who provided the technology and want to see it applied.

For the next 3 days we hope to assess the state of the art, assess our responsibilities and capabilities, and finally define a future course of action that takes advantage of both. I assure you that we are not just paying lip service to these tasks and we are actively seeking guidance and constructive criticism with which we can define these new objectives.

STATE OF THE ART--CHEMICAL CONTROL

Conventional Herbicides

by

Kerry K. Steward

The art of chemical weed control is a function of chemical tools available and the technique of application of these tools. I will quickly run through a list of approximately 20 compounds registered nationally by the U. S. Environmental Protection Agency (EPA) for aquatic weed control and try to illustrate some of the conventional techniques of application of these chemicals. I will close with some examples and a list of promising new chemicals that are in the process of development.

For floating weeds, such as duckweed and waterhyacinths, we have amitrol T, diquat, silvex, and 2,4-D. Some of these compounds will be familiar to the people who use them and will probably be meaningless to others of you who are not familiar with them.

For immersed broadleaf weeds, we have silvex and 2,4-D; for water lilies, dichlobenil; for sedges and grass, we have amitrol, amitrol T, and dalapon; and for bullrushes and cattails, we have amitrol, dalapon, and 2,4-D.

For submersed weeds and algae, we have various forms of copper--organic copper, copper sulfate, copper carbonate, etc., and dichlobenil, diquat, endothall, fenac, silvex, simazine, and 2,4-D.

For irrigation and drainage ditch banks we have amitrol T, dalapon, dicamba, dinoseb, diuron, hexazinone, krenite, TCA, 2,4-D, and possibly others. For irrigation and drainage canals we have acrolein, aromatic solvent, copper, diquat, diuron, and endothall.

One of the techniques of application is a conventional Corps of Engineers spray boat. Because of the problems of accessibility in some remote areas, it is hard to use a regular spray boat for application. Airboats are also used in some situations where the submersed weed growth is dense and it is difficult to get a boat through. One problem that you encounter occasionally in chemical weed control is that of drift of chemicals onto susceptible crops. The drift problem can be

rectified with an invert emulsion; however, the use of a polymer, a PBC polymer, can reduce drift considerably, preventing some of the problems.

Another technique of application to ditch bank weeds is invert emulsion using a multiple spray nozzle. A mechanical inverter can be used which is just a trailer rig that can be mounted on boats or on the back of a truck.

Another technique of application is aerial application. Helicopter application can be used on a drainage ditch bank for control of ditch bank weeds and also on submersed weeds. In an experiment in a barrow pit in Florida, equipment was tested on applying herbicides to control waterhyacinths. The Amchem Directa-Spray gives drift control plus the addition of a polymer. Subsurface application of herbicides can be used for a submersed weed problem. Discharge of the pump is into the manifold through trailing hoses with weighted nozzles. The subsurface application can be used for conventional chemicals or inverts or even a polymer. The technique of invert emulsion is being used in Florida to reduce the amount of chemical being used and to get some selective placement of the chemical on the weeds. Normally one would break up the invert into particles that would settle onto the plant. An invert is nothing but an emulsion mixed with an oily material, either diesel oil or xylene. Water is added to this mixture which forms a very thick viscous material. Another technique, using Hydrothol 191, propylene salt, and endothall mixed in a research application with a polymer, also forms a heavy, viscous material that acts as a carrier causing the material to sink onto the plants thereby restricting the amount of material used and restricting the chemical just to the plant surface. In this manner, instead of treating the entire column of water, you can restrict the treatment just to the plant itself.

This technique using polymers also works very well in helicopter applications. A good operator has very good control of the placement of the material in cases where selected placement is desired.

Applying herbicides in granular material gives a spot placement or a restricted movement of the herbicide. Many granules and techniques

of applying granules are available. One such example is a cyclone seed spreader located on the front of an airboat with a blower. The material is poured into the hopper, into the air stream, and is then blown out. Another large granule-spreading operation is a spinning disc on a helicopter. Close to a million pounds of 2,4-D granules can be applied with equipment such as this. Soil sterilents can be applied to reservoirs that have been drawn down also. Another technique of attempting to control submersed weeds involves a combination of draw-down and an application of herbicides.

Rototilling herbicides into a ditch bank is another application of applying herbicides. Acrolein, or an aromatic solvent, can be injected into irrigation canals. It's difficult to control weeds in flowing water. You need a very hot material that will kill on contact. Techniques have been developed where you can apply materials in flowing water and get a fairly good control.

Briefly, I will describe some of the herbicide screening work we are doing at Fort Lauderdale. We culture hydrilla in concrete tanks for these screening trials. A new material, hexazinone, at half a part per million gives control for nearly a year. This is a material that would give long-term control because it is persistent. Hexazinone, or Velpar, at a kilogram per hectare was found to be much more effective against waterhyacinths than 2,4-D since 2,4-D generally requires 2 to 4 kg/ha. Therefore, it is a promising material for control of a broad spectrum of weeds and is a good algacide as well.

Field applications of fenac controlled hydrilla infestations for about 18 months, which is unusual for hydrilla. Hydrilla can often grow back in 3 months. We've found Velpar and terbutryn to be very effective against hydrilla. Fenac is a material that has been around for a long time but is now being developed for use in the total water treatment. Some promising new aquatic herbicides that we have been working with include fluridone for submersed weeds; hexazinone and metribuzin for floating weeds and ditch bank weeds; and buthidazole, a promising new material of Ilpar Products, that is being developed for submersed weeds.

These, again, are the materials of the companies that we're working with in the development of these products. So there are things coming down the line that do look promising and, with any luck, we'll have some newer and safer material to work with in the future.

STATE OF THE ART--CHEMICAL CONTROL

Controlled-Release Herbicides

by

Frank W. Harris

What I hope to do in this presentation is give you a general knowledge of the research that has been carried out in the area of controlled-release herbicides. In effect, I hope to give you some idea of where we stand in the process of developing these materials and then, at the end, I intend to point out the directions that I feel this research should take in the immediate future.

Two general types of controlled-release systems exist: physical systems, which consist of herbicides simply physically entrapped in a solid matrix; and chemical systems, in which the herbicide is actually chemically bound to a polymer background.

In the physical system, the solid matrices that have been used include synthetic plastics, elastomers, waxes, and several naturally occurring polymers. Release generally occurs by a diffusional type process, either simply diffusing through the matrix into the aquatic surroundings or the water actually penetrating the matrix and leaching the herbicide from the material.

Some of the plastics that have been used include polyethylene, polyvinyl chloride (PVC), and various polyamides. We have spent a lot of time with polyethylene formulations, in particular, formulations with fenac acid; in fact, some of these materals have been tested at the University of Southwest Louisiana and were found to work well against waterhyacinths, egeria, and watermilfoil. These are several parameters that we have determined actually affect the release of these herbicides from polyethylene. We can vary any one of these parameters and, in effect, change the release rate.

One parameter, the configuration of the final product, actually has a lot to do with the release rate profile obtained. Several herbicides have been put into PVC. I should point out that a PVC endothal formulation has been tested by Kerry Steward in his laboratory and was

found to be very effective against hydrilla. He also tested a PVC fenac formulation which looked good against southern naiad. Some of the elastomers have also been used as solid matrices. There is a whole series ranging from truly synthetic elastomers to naturally occurring rubber. A formulation of 2,4-D, butoxyethylene ester in a natural rubber base, was tested by the Corps' Bill Thompson in Louisiana. He found that a series of these materials was fairly effective in control of waterhyacinths in some irrigation canals. There was also another formulation of the 2,4-D BEE ester in natural rubber that was quite good against egeria in a lake.

The parameters that affect the release of herbicides from the elastomeric bases are somewhat the same as with polyethylene. There are a lot of different ways you can change the release rate.

The chemical systems are a little bit more complicated in that, as I pointed out initially, the herbicide is actually chemically bound to a polymer backbone. These systems release the herbicide by a chemical reaction with the water. The water reacts with the polymer containing the pendant herbicide and you get cleavage. This is a continuous type process that takes place over a long period of time. In fact, we have formulations that release a milligram of herbicide per gram of formulation per day for up to 2 years, so this can be extended over a long period of time.

We have determined that the degree of hydrophilicity affects the release of herbicides. For one thing, we know that if the system does not attract water, it will not hydrolize. In other words, the herbicide will just stay on the backbone indefinitely. We know that the type of chemical bond that you use can greatly affect the release rate. We know that we can change the system by cross-linking it and once again get a different release rate profile. Configuration of the final product is important and the surrounding conditions often are very important. In other words, the pH and the temperature of the surrounding water will affect the rate at which the bonds will cleave.

Concerning the degree of hydrophilicity, what we do is take a system and incorporate in that system some hydrophilic roots along

with the herbicide molecules, and by varying the amount of something as simple as an OH group, something that attracts water that we put on that backbone, we can effectively control the rate at which the herbicides are released from the backbone.

Of the different linkages, a hydrophilic linkage releases fairly quickly in water; the ester linkage is used most commonly; and the amine linkage hydrolizes very slowly. In a cross-link system you have a polymer containing some hydrophilic root that has been cross-linked by some cross-linking agent.

When you compose a system of this type, as discovered in previous cases, the polymers actually go into solution as the process proceeds; therefore, everything eventually ends up water soluble. In the case of cross-linkages, the final products are not water soluble. The final matrix material after the herbicide has been released is not water soluble due to the cross-linking. However, we have obtained some very good uniform release rates with cross-linkage. Another thing I might point out about cross-linkage systems is that it is possible to obtain a very high degree of loading of the herbicide material. If you compare the molecular weights of the herbicides we are using with the molecular weights of the polymers, you see that the molecular weights of the herbicides are much higher; so, in effect, we have a material that can be as high as 80 or 90 percent herbicide--although it is a polymer, it is still 80 or 90 percent active ingredients.

Some other acquired knowledge in this area of controlled release has been the discovery of the chronicity phenomenon, which simply states that in low concentrations the traditional dosage response laws don't seem to hold and that you can obtain control by exposing the plant to a very low dosage over a long period of time. If you want further information about that, you can talk to George Janes of Creative Biology Laboratory, Inc., who has spent a lot of time working with this phenomenon. In fact, George has recently been working on this concept of release rate versus delivery rate. We have to adjust our release rate so that we are effectively delivering enough material to control the plant, to compensate for the plant acting as sink in taking up this

material. These are some of the things we have to take into consideration. In fact, just talking to Gene Addor, who's testing one of the polymer systems, he's found out that that particular system was a very good growth stimulant because it releases 2,4-D at such a low level that it stimulates growth. So instead of killing it, it's stimulating its growth.

We can change the delivery rate by the parameters I mentioned before, hopefully to kill the plant.

The first step in the research and development of control with these formulations is that you have to be able to prepare the formulation, because there are some formulations that cannot be prepared. You cannot put every herbicide in every base because there are some that are basically incompatible. The second thing that you have to do is determine the release rate, which is not always a simple process. It can be a very time-consuming process because, as I said, we are looking at systems that release over long periods of time. Therefore, it takes a considerable amount of time just to get the release rate profile. The third step can actually be considered a two-level step. While determining the parameters that affect the rate you can also be testing for the efficacy of the formulation. In other words, what you have to do is show initially that the herbicide prepared has not been changed chemically and that when it releases it still retains the ability to kill the plant. It is possible that the compound chemically changed some way and is no longer toxic. Therefore, one of the first things to be done is to actually test for conventional efficacy.

Once the elemental facts have been established, you can go into product development, which is where you take one of these formulations and push it on down the line and try to get it into the field so that it can be used as an operational tool. One of the ways that you do this if your material does not have any efficacy is to modify the formulation. If you've already determined the parameters that affect the rate, that's no problem. You just change one of these parameters in the direction that you wish to go and retest. Once you get past the test for conventional efficacy, then you can test for control

release efficacy. In other words, will this material provide long-term control of aquatic vegetation or other test species? There is a real problem with this. If you stop to think about it, how are you going to carry out this type of test. As far as I know, no one really has a good test for control release efficacy. There just hasn't been a good one developed. What you might do, ideally, would be to treat an aquatic system with the formulation, see if it controls the vegetation, and see how long the system remains clear of vegetation; however, that is a very time-consuming process and a very expensive one. What we'd like to have is some way to conduct this in the laboratory, a very small-scale test. I should also point out that one of the things emerging from all this is that when you're talking about long-term control, what you're probably going to have to do with the control release system is go in initially and treat with a more conventional system. In other words, get your problem well controlled initially with a conventional system and come back with a control release system that can function as a plant growth regulator. In other words, it will prevent the regrowth of the vegetation in the system.

After we get to this stage, we test for control release efficacy, we see if it works, and if it doesn't work, once again, it's not too difficult to modify the formulation. Finally, once control release efficacy is determined, we can move on to the large-scale field test. It is not unusual for formulations to get only to the release-rate testing stage. I don't know of any that have made it as far as being used as an operational tool. So there are several hard decisions to be made; namely, which ones do you want to push on through? These decisions will result in expenditures of considerable amounts of money.

To put this all in perspective, the facts that I've presented, to the best of my knowledge, have been gained at the cost of only about $300,000. I tried to add up every cent I could find that has been expended on the development of controlled-release herbicides. The best I can tell, that's a generous figure, it's actually more like $250,000. So there really hasn't been a lot of money put into this type of work yet. I know some people say "Why don't we have a product

already?" Well, if you have any concept of how much research costs, and I'm sure a lot of you do, you realize that $250,000 or $300,000 expended over a 9- or 10-year period isn't very much.

Just to give you some idea of the cost of research, I was wondering what amount of money goes into cancer research. The figure I came up with for 1969 was $180 million for that 1 year for cancer research. Putting it even more into perspective, if you talk to people of companies that are bringing new herbicides on the market, they will tell you that the whole process costs several million dollars. Therefore, personally, I feel we've come a long way in this area, and that we're getting close to going into product development. The next couple of years should be interesting, and I think it won't be too long before we're going in to controlled-release materials. We already have some in quantity and it won't be too long before we have tanks and cans for actual field use to see if they work like we think they will.

STATE OF THE ART--BIOLOGICAL CONTROL

Control with Insects

by

Ted Center

I had a lot of difficulty arranging a talk on the subject of the state of the art of biological control. To illustrate the reason for my difficulty, I need to define biological control. The textbook definition is, "the regulation by natural enemies of another organism's population density at a lower average than would otherwise occur." The textbooks are quick to point out that the manipulation or activity of man is in no way implicit in this definition. Yet a topic such as "the state of the art" definitely refers to the activities or manipulation by man. The resolution of this problem comes in the fact that man uses biological control, or tries to facilitate the activities of these organisms to maintain pest population densities at a lower average than would otherwise occur.

The first example of biological control that's been documented was in 1762 when the Mynah bird was imported to Mauritius from India to control red locusts. This was the first case of biological control here and essentially what happened was an organism was taken from one country to control a pest in another area. It involved the movement or importation of a predator to control a pest. This is where the state of the art stands today. It essentially hasn't changed from that point.

Let me take you historically through the development of biological control in general, and in the end we'll get to the biological control of aquatic weeds. Probably the first large-scale program that was done on more of a national level was the Vadelia Beetle Cottony Cushion Scale project in California. Cottony Cushion Scale threatened the California citrus industry with destruction. No effective control technique existed. The disease was running rampant in California, having the growers very worried. Finally, the U. S. Department of Agriculture sent an entomologist to Australia to look for natural enemies. He found a Vadelia beetle, brought it back, and released it. It has almost completely

controlled the Cottony Cushion Scale to this day. The total cost of the program was less than $5000; the benefits have been millions every year since.

The first biological control program on weeds was probably the prickly pear cactus program in Australia. Prickly pear infested 60 million acres, almost completely blanketing the land in some areas, making the land totally useless. The Australians imported a moth from Argentina, Cactiblastus cactorum, which today almost completely controls prickly pear. The benefits are almost inestimable. The first activity of biological control on a weed in the United States came about in the 1940's. The United States was very reluctant to bring in a plant-feeding insect for obvious reasons. The insects were two species of the leaf beetle, Carcelena. The beetles were recognized about 30 years earlier, but it wasn't until 1940-1946 that they were finally introduced in the United States. The beetles were introduced to control klamath weed, primarily a rangeland weed that resulted in depreciation of property values and loss of weight of livestock. To date, the beetles have done a very good controlling job; it's been estimated that the benefits from this program are about $3.5 million per year, which has been accruing since 1953.

The first biological control aquatic weed program was alligator-weed. This was followed by waterhyacinth, which we're in right now and in the process of phasing out, and are now moving into hydrilla and Eurasian watermilfoil. Alligatorweed is a floating, mat-forming plant that may be rooted to the bank. Three insects were introduced to control alligatorweed: Agasicles hydrophila in 1964, Vogtia malloi in 1971, and Amynothrips andersonii in 1976. Agasicles is a flea beetle, Vogtia is a pyalid moth, Amynothrips is a thrips.

After a fairly successful program with alligatorweed, the Department of Agriculture moved into waterhyacinths like Eichhornia crassipes. Waterhyacinth is a floating plant that can cover large expanses of open water, making them almost impassible. We also brought three insects in on this: Neochetina eichhorniae in 1972, Neochetina bruchi in 1974 (these are both weevels), and Sameodes albiguttalis, a pyralid moth which has

just been released within the last year. The adults of *Neochetina eichhorniae* feed on the leaves causing small round lesions. Eggs are laid in the leaf tissue. The larvae burrow down through the leaf petioles and ultimately into the rhizome of the plant. As they mature they move into the roots, form a cocoon with the root hairs, and pupate there. The life cycle of *Neochetina* is long, about 50 to 60 days. They lay relatively few eggs per female, and the amount of damage per insect is fairly small. Therefore, any control we might obtain with *Neochetina* is contingent upon very large populations. The third insect, *Sameodes albiguttalis*, lays eggs in any kind of lesion or scarification on the leaf surface. The larvae hatch. They may feed externally, causing abrasions of the leaf epidermis. The first instar larvae are very tiny. Ultimately they move into the petiole which they completely hollow out, finally moving down into the center of the plant. This is very important because they go right for the apical bud and destroy it. After they complete feeding, they move back up into the petiole and pupate. They then emerge as adults; the nice thing about this one, compared to *Neochetina*, is the very short generation time, about 30 days. They have a very high fecundity, they lay up to 200 eggs, and they cause a high amount of damage per insect. We expect a lot from *Sameodes*, although we have not field tested it long enough yet to see how well it's going to do.

Right now we're concentrating on trying to get *Sameodes* established in as many sites as possible within a band across the southern part of the State of Florida, using essentially the Tamiami Trail as the southern boundary and Alligator Alley as the northern boundary. We have released at seven sites and have them established at two, possibly three, sites. We conducted one release in the Miami Canal and came back about a month later and found out that we had a population going. We contacted the people of South Fort, a water management district, and said "Hey, we've got an insect going on the waterhyacinths in Miami Canal and we want them protected." And they said, "Waterhyacinths on the Miami Canal? We didn't know that." They sprayed them! Therefore, one of our major problems has been trying to keep a site free of herbicide treatments.

We're now beginning a program on hydrilla and Eurasian watermilfoil. It's been building for several years, but we hope to begin study in earnest within the next year or two. How do you develop a program like this? What is the technological approach?

First, there are the preliminary steps. Obviously the first one is to select the weeds. In selecting a weed you need to ask three questions: "Is it an important enough pest to warrant a full-scale biological control effort?" "Can it be economically controlled by other means?" and "Do you have a chance of success with biological control?" If there's enough interest in the weed you can skip the "chance of success" question and proceed. We recognize the fact that both hydrilla and Eurasian watermilfoil, being submersed aquatic weeds, are going to be rough problems. The problem is going from a floating habitat to a submersed habitat which is a whole new ballpark for us. We know almost nothing about herbivory on submersed weeds. Therefore, selection of these two is not because they are optimal choices for success, rather they are so important that the attempt needs to be made.

The next step will be to survey for natural enemies already present in the area where the plant is a pest. This is the phase we are in right now. Dr. Balchunes is working for us; he surveys hydrilla and Eurasian watermilfoil and finds out what insect predators are already established. His work will prevent us from considering those same insects overseas later on if we find an organism that occurs both here and in other parts of the range of hydrilla.

You then need to determine the worldwide distribution of the weed. If we want to find natural enemies somewhere else, we need to know where the weed grows in other areas. We then compile a listing, primarily from the literature, museums, etc., of the known natural enemies. This gives us a basic list of candidates to start sorting from and narrowing down. You may start out with 200 to 300 candidates in a program such as this and wind up introducing only 1 or 2. For this reason, we need to know essentially all the natural enemies known to the weed. The final preliminary step is to survey for new natural enemies if there is a lack of sufficient candidates to work with. A decision must now be

made. Essentially, these decisions are the art of biological control. Which way do you go? The insects will do the control themselves, but determining the approach is where the state of the art is, I believe.

Do you manipulate those natural enemies already at hand? This looks good on paper and sounds good in theory. There is, in fact, some work already being done on this. Chuck Quimby is working with Arzama densa on waterhyacinth, a native insect that attacks waterhyacinth. It is a feasible approach, but it is one that is rarely taken. The usual approach is to search for new natural enemies in other areas of the world. There is a good reason for this--50 percent of our aquatic weeds are of foreign origin. Naturally it seems reasonable to look for natural enemies which are of foreign origin also.

After determining to use the new enemy approach, there is another series of steps to follow. These enemies have to be collected and studied throughout their host range; it must be determined if they're going to do enough damage to warrant further study, whether or not they're specific to the pest plant, and that they will not attack economically important plants. The study must also determine how they are tied into the biology of their host plant. As with Neochetina, such things as their life histories, fecundity, rates of increase, etc., must be studied. We then want to summarize this information, ascertain if it's going to be a useful insect or not, make sure that it is not going to attack economically important plants, convince the appropriate officials that it is a useful and safe insect, and get permission to introduce it and acquire all the necessary permits.

The last step, and this is one where I think our aquatic weed program really stands out in terms of other biocontrol programs, is assessing the efficacy of the insect. We not only determine the effect of the insect on the plant, but also how the plant responds to the insect, if anything can be done to enhance the effect of the insect, if the program should stop there, or if we need to go back. This step provides very good feedback. For example, with Neochetina our data show that the adults lay eggs in the older leaves, after the leaves

start to deteriorate, when they're no longer functional. This has resulted in much less damage than was expected from the insect. However, Sameodes is doing just the opposite; they're heading right for the middle of the plant and attacking the new young leaves. This produces a complementary system; Sameodes in the middle of the new leaves, Neochetina attacking the older growth. By taking this last step of assessing the efficacy, we are able to come up with complementary insect control methods. Kerry Steward and I are currently working on using a growth retardent to try and slow the plants growth enough so that Neochetina can control it. It looks now like Neochetina will control the rate that the new plants are produced whereas the retardent controls the size of the plants produced. Again, we can get a very complementary type of control approach.

What stage are we at now? We are phasing out alligatorweed altogether, and we are gradually finishing with waterhyacinth. We are in a transition from floating aquatic plants to submersed aquatic plants. We know very little about insect interactions on plants in general, virtually nothing about insect/plant interactions on submersed aquatics. It's a whole new area for us and it's quite a challenge. I think it's going to be several years before we come up with anything for controlling submersed aquatic plants, but it's going to be interesting.

STATE OF THE ART--BIOLOGICAL CONTROL

Control with Plant Pathogens

by

T. E. Freeman

Biological control has been going on quite awhile, but man's manipulation of it has not. As far as plant diseases are concerned, we were rather late in starting. Dr. C. L. Wilson wrote a review article in the annual review of phytopathology in 1969 which he ended with a commencement rather than an ending, because he said "We are just beginning to work in the area of biological control, and especially the biological control of weeds and plant pathology." Entomologists have been at it for quite awhile, for example, in 1920-1925 with Cactiblastus moth on prickly pear. Ted Center forgot to mention that they also imported a soft rotting bacterium along with that moth that helped wipe out that cactus. But that was purely coincidental, one of the hazards of the biocontrol programs. At any rate, we were late getting started into the game, especially in the field of aquatics. About the time that Dr. Wilson's review article came out we were thinking about starting a program at the University of Florida to study the use of plant pathogens for the control of aqautic weeds. At that time, or shortly thereafter, Dr. Zettler and I wrote an article on the review of the use of plant pathogens for the control of aquatic weeds. We really had practically nothing to review, and I guess we were somewhat rough on plant pathologists for not realizing the potential that lay out there at their doorstep. There were some other programs around, true, but certainly not with aquatic weeds at that time. Dr. Templeton was starting a program on the control of weeds in crop plants in Arkansas at about the same time.

In 1969 or 1970, Dr. Zettler and I formulated a program of methods for aquatic plant control. Those methods are still the primary ones used for the control of aquatic weeds: herbicides, mechanical devices, and various biocontrols. Some of the variations seem rather ridiculous as we look back on them, but they have all been used. Plant pathogens

was the last method to come into play as far as research for their use as potential biocontrols. The reason is that the plant pathologist over the years has developed as a man closely associated with agricultural industry in the United States and other countries of the world. He's concerned himself with terrestrial plants, especially the crop plants among those terrestrial plants. He has been concerned with controlling diseases and saving plants from diseases. It never occurred to him to use diseases to ravage undesirable plants such as weeds. He simply let the man with the mule and the plow take care of the weeds while he took care of the diseases that affected the crop plants. If he avoided weeds in terrestrial situations, he doubly avoided weeds in aquatic situations. In fact he avoided all aspects of the aquatic situation including aquatic crops, and there are a few aquatic plants used for crops. Most of all, however, he avoided looking at the diseases of weeds, and thereby he made a mistake and was late entering the field.

We started a program on the use of plant pathogens for biocontrol about the time they decided that the flea beetle was working quite well on alligatorweed. So that gives you some idea of where we are in the program.

Certainly plant pathogens have many distinctive characteristics that make them ideal candidates for biocontrols. By their very nature they are diverse. It has been estimated that there are 100,000 plant pathogens in the world. Practically all plants have their set of diseases just like human beings have theirs. Many of these plant pathogens are highly host specific. They will attack only one species, and, in fact, some of them are specific down to the variety level. They will only attack one variety of one species. Therefore, they can be highly host specific, and this is because of their genetic makeup.

The plant pathologist spent a considerable amount of time developing his basic research in the area of crop production and came out with one theory called the "gene-for-gene" theory. For each gene for a pathogenistic fungus or a plant pathogen, you have to have a gene for susceptibility in that plant. Hence, it becomes a highly host-specific type of situation, a very intimate host/parasite relationship. Plant

pathogens are easily disseminated. They can be scattered around in any of the ways that Kerry Steward showed you for scattering chemicals. They can also be scattered around by natural elements such as wind, water, man, animals, etc. They can usually be grown in abundance; we have evidence of this fact coming through the work of some of our industrial people with various laboratories. Abbot Laboratories is researching the production of biological agents, plant pathogens that can be sold right off the shelf and used for control of plant diseases. They are very nearly reaching that approach. Of the other laboratories, Upjohn Company is doing the same thing with Dr. Templeton's work with pathogens that affect weeds in crop situations. You can see that we are reaching a point where we can produce and easily disseminate these plant pathogens.

The pathogens seldom eradicate a host, even in a given location and a very specific location. This is good in certain respects. I don't think we'd really want to wipe out the waterhyacinth entirely. It has a pretty flower and a lake with a fringe of it makes quite a nice looking body of water. Plant pathogens will decimate a population, but they seldom wipe out that population. Also, they are safe to use from the standpoint of attacking man, his animals, wildlife, or fish. We haven't proved that definitely, but we are fairly sure. One of our prime biocontrol agents for waterhyacinths will not grow at 35^{o}C, for example. It just sits there. It won't grow even though it stays alive. It wouldn't make a very good pathogen on man when man's body temperature is 37.1^{o}C. Therefore, we think they're relatively safe to use from the standpoint of their effects on man, but we're still going to have to prove that.

Now what are some of these plant pathogens? We said they are diverse. We have fungi; they are the predominant ones in the group. We also have bacteria, virsuses, and nemitodes that affect plants. They are all plant pathogens. Now how do we use these? The plant pathologist has taken two approaches. The first approach is the use of endemic plant pathogens, a pathogen that occurs naturally in an area, which augments the population to a point where it will cause an epidemic within a species. Now this is exactly opposite to what the plant pathologist

is trying to do with crop species. He's trying to stop an epidemic. If we're going to use these pathogens for the control of plants, we have to start an epidemic. Hence, we're using them somewhat like a biological herbicide, or, as Dr. Templeton refers to his, a microherbicide. This is exactly what we're doing; we're augmenting a disease situation that is already there. Ted said it didn't work too well with insects. It seems to hold more potential in the area of plant pathogens.

The second approach is to search for exotic plant pathogens, ones that do not occur in the area. We then go through exactly the same steps that Ted Center outlined for you in his talk to introduce a plant pathogen from a foreign country and establish it in this country. The same set of circumstances apply.

As an example, let's consider the fungus Cercospora rodmanii, one which was discovered by Dr. Conway, formerly of the program of waterhyacinths in Rodman Reservoir in Florida. This fungus caused quite a bit of damage there. Dr. Conway isolated the fungus and we studied it. We can grow Cercospora on a small scale in the laboratory. We grow Cercospora in bottles, collect the material, grind it up with a large commercial-size Waring blender, and spray it on the waterhyacinth. Cercospora, once started in a small area, can be spread around by wind currents into the rest of the lake. In a 2- or 3-acre area the disease can develop within the space of 2 or 3 weeks after spraying. It can also be used in combination with other materials such as other biological agents (for example, Arzama, Neochetina, Cercospora, and Acremonium zonatum).

In an experiment in Lake Conway, Louisiana, along with Ted Center and his group and the Corps of Engineers, we achieved a drastic reduction in biomass when teaming up on waterhyacinths with biological control agents. This may be another route we can follow.

Some of the problems involved include the fact that we have to prove host specificity. When working with the Cercospora fungus, we grew it out and sprayed half of it on different kinds of plants planted in a garden area; we then sprayed the other half on waterhyacinths to make sure it was pathogenic; we then checked for any disease. We'd

gone though this for about 85 different plants, plants closely related to waterhyacinths as well as regular crop plants and plants of ecological importance. This has to be done to ensure that you have a safe pathogen.

There are drawbacks involved in studying pathogens. Acremonium zonatum, the so-called zonate leaf spot, attacks large plants much more vigorously than it does small plants. Cercospora is almost the opposite and we need to know why these smaller plants are resistant, why we can't kill them. In fact these larger plants, as time goes on, also build up a resistance to the fungus. A graduate student working on the problem found out that waterhyacinths possessed a large amount of phenol, which is naturally fungi-toxic. The waterhyacinths have phenol storage cells, which is very unusual in plants. Only a few other plants have them, and they are highly resistant, in general, to plant diseases. Therefore, we feel that waterhyacinths have a high inherent resistance to plant disease and we need to find a way to overcome this resistance. We may be able to do this through combinations of growth regulators and materials of that nature to overcome this particular resistance mechanism. As you can see, it is a problem. We know all about resistance and susceptibility in crop species, but very little about it in weed species.

One other problem that we're all aware of is the need to guarantee that we will not endanger the environment when we use these biological agents, especially plant pathogens. This also goes for insects and all others.

There is a certain amount of danger involved in putting anything in waters, and we have to be sure that what we're putting in there is safe. This is a drawback to the use of plant pathogens.

Another drawback is that we are not as technically advanced in working with underwater plants as we are with above-water plants. Just as Ted Center said that they know very little about insects and the host/plant relationship with the insects underwater, we're in the same shape with plant diseases underwater. We don't know as much about it as we should. We need to work more diligently in establishing a host/parasite relationship that exists in the aquatic environment as opposed to an

aerial environment. So, you can see the basic problems we need to solve in working with underwater plants.

Of course, we also have the problem with people who just don't think you ought to be fooling around with Mother Nature--"That's a pretty plant and why do you want to kill it?" I've been asked that a dozen times by people who, ordinarily, you would think would understand.

These are just some of the problems that we face with plant pathogens; however, despite that, we feel that the plant pathogens have great potential. There are other diseases being researched and still others that need research. We need to study some of the diseases, especially the viral diseases that affect algae. We need to expand and work more diligently with the underwater plants and learn how to work with diseases affecting those plants. We feel as if we have made a valiant start and are coming out of the Dark Ages and into the Renaissance with the state of the art in plant pathogens for biocontrol of aquatic weeds.

STATE OF THE ART--BIOLOGICAL CONTROL

Control with Fish

by

Robert Lazor

When looking at the state of the art, or the state of the science, of herbivorous fish, I think we should first touch base with an outline of some of the various types of fish that have been utilized in the past or may be researched in the future. We must always mention the talapia, of which there are over 100 species, some of which have been introduced into the State of Florida. These are mouth breeders, which means that they lay their eggs and the fry hatch and reproduce within the mouths of adult fish, so that rather than getting a one-to-one replacement ratio on your reproduction, you may get 99-to-1. The use of talapia has ceased as far as research operations within the State of Florida. They were released in the central part of the state in highly utrophic lakes where they flourished and replaced many game fish. There are heavy populations of them still in polluted lakes in the central Florida area. The silver carp is certainly another exotic carp that has some potential, primarily for algae control. Control would probably not be of the filomentous benthic algae but more likely the planktonic algae which plague many counties in the central part of Florida. The State of Florida has initiated a mullet study in which the feasibility will be studied of using mullet in inland freshwater systems of the state, trying to get over the hurdles of spawning, artificial spawning, and reproduction and some experimentation in small ponds. The word that would best characterize the basic research and the operational management system within Florida and within the United States is "controversial." Let me give you the track record as far as a state-by-state status report and then come back and talk a little bit about the Florida experience.

Florida obviously is the testing ground for Federal Agencies, both the U. S. Army and the Department of Agriculture. It's also a testing ground for the State of Florida and there are a great many people looking

to Florida for information. Within Florida, the present situation is one of limited use, guarded optimism, basic research, and operational management.

The State of Alabama prohibits the importation of the grass carp into the state. However, you may possess them within that state. Georgia has a ban on the importation and on the possession within the state. However, they are pursuing a very active research program. The Arkansas experience has been characterized by introduction, aquatic plant control, and aquatic plant management. They've really gotten good control in their state, but I'm afraid it's like the use of 2,4-D--for 20 or 30 years it was used and nobody really understood the basic mechanism of how it worked.

In the Panama Canal Zone, there's an interesting experiment going on with the use of the grass carp in Gatun Lake.

Within the United States, we have 33 states that have outright banned the importation and the possession of grass carp and very few of these are even actually doing any research. These are what we call the "ostrich" states, the ones that have stuck their heads in the sand and hope that it will go away.

We are now going to hear from L. V. Guerra from the Texas Parks and Wildlife, Donald V. Lee from Louisiana Department of Wildlife and Fisheries, and A. Leon Bates with Tennessee Valley Authority (TVA) about grass carp in their area.

<u>L. V. Guerra</u>: "I told you if you asked me to speak, you were going to be embarrassed, because what I have to say, you probably won't like. We've had your local experts come down to Texas and appear before our commission, and they did not make a favorable impression at all. However, we do not go along with the theory that 'so goes Florida, so goes the Southeast.' The facts we have in Texas say that the grass carp has been accepted by 32 states, but you just said that it has been banned in 33. This has been typical all along of the type of information we get. We get one type of information from certain groups but when we sent three people to the State of Florida, they came back with entirely different information. The people in Texas wanted to send me, but they

knew my feelings in the matter, so I didn't go to Florida. I've been there before and I knew the routine. I'm still not impressed. However, I have respect and admiration for you fellows that have your heads on the chopping block. I would like to remind you that the last State Commission of Texas that permitted the introduction of carp was disbanned by the Governor. I think that the present commission is swayed by the feeling that we don't need another rough fish."

Donald V. Lee: "Louisiana is almost in the same boat. Currently, the state prohibits the introduction and possession of the fish, but there is a permit system by which recognized research institutions can bring the fish in for research purposes. It is my personal opinion that even though the research conducted by the Department of Wildlife and Fisheries over the past 6 years indicates that the fish has not caused any adverse affects to the water bodies under study, the fish will not, within the next 10 years, be introducted into Louisiana."

A. Leon Bates: "I think by and large that the situation in the Tennessee Valley is that we have one problem species of aquatic microphytes, Eurasian watermilfoil. The work that we've conducted, and some of the work that others have done, indicates that watermilfoil is low on the preference list of the white amur. So I really don't think there's going to be a solution with introduction in the Tennessee Valley. Most of our impoundments are very large and there are still a lot of questions to be answered concerning large impoundments. We're very much concerned about a native species of plants and we'd certainly want to know that story, too. So, by and large, I think that the white amur is not a good candidate for introduction in the Tennessee Valley.

In other areas, Auburn University is proposing stocking farm ponds in the State of Alabama. Tennessee and some of the other states in the Valley have an importation ban on the fish. This sort of brings you up-to-date on the TVA system."

Robert Lazor: I would encourage anyone at the State or Federal level to try and digest as much information and talk to the people in the states, whether they've approved it, experimented with it, or banned it, and form your own judgment or opinion.

Let me briefly outline the system of events of grass carp research in the State of Florida that we will call the "Florida Experience."

To give you a little life history of hydrilla, it is one of the submersed noxious water weeds that was imported into the United States and into the State of Florida early in the 1960's. One hydrilla characteristic that we are worried about is its tubers and turions which are underground and above ground. The propagules are active growing points that look like they're surrounded by leaf tissue and they can stay dormant in hydrosoil and then undergo germination at later periods.

The grass carp have pharyngeal teeth that are responsible for so much of the weed control. There have been a great many studies done in Florida that have been either aquarium or swimming pool oriented. Research studies on the white amur in Florida have progressed from pool tests up through the so-called "four-pond" study to the "six-lake" study. Most of you here are familiar with the Federal Lake Conway Study which WES is conducting. The Army Corps of Engineers has pretty well been the lead agency at the Federal level for operational management utilizing the grass carp for aquatic plant control. Going into a little bit more detail, within the State of Florida, the U. S. Department of Agriculture is considering a large-scale operational test in conjunction with APHIS, the Animal and Plant Health Inspection Service. Together they will be evaluating a field test for the eradication of hydrilla, pursuant with the Federal Noxious Weed Act. It is required under that law, which was enacted in 1974, that before a noxious, exotic water weed could be treated, it had to be proven that it could be eradicated, at least on a regional basis; other than that it would not be considered under the law.

Florida will be the proving grounds for this Department of Agriculture eradication test, the Federal Lake Conway Study, and within the State of Florida we have what we call the limited use rule on the grass carp. This rule designated primarily three noxious water weeds. You had to have 10 percent coverage of your water body before you could apply for a permit. In cooperation with the Florida Game and Fresh Water Fish Commission, this rule is being revised to include native and exotic submergent water weeds; progress on the rule changes from day to day.

In summary, Florida is for an expansion of the grass carp rule to go into more private waters and into more submergent weed control within private waters. Another major emphasis within the State Agriculture Department is on the development of a grass carp label. This is one of Dr. Burkhalter's major efforts; we labelled herbicides, we're certainly going to label pathogens, and we're going to label the grass carp. There already has been a preliminary label developed.

Work on the original label, which is being developed now, has considered all the basic research and operational data which are user-oriented. By user-oriented, we mean whether or not grass carp will be used for irrigation systems and where it will be used for fisheries' management, navigation, and waterfowl. We've gone to the available literature and to all the operational data we could find and put together a stocking rate based upon pounds of fish per acre of water weeds. We're still in the primitive stages with this and, hopefully, the limited-use rule on the grass carp will provide much information for the development of the grass carp label. This study is being conducted in cooperation with our Game and Fresh Water Fish Commission.

To sum up the situation, Florida agencies have been working on the grass carp as have the U. S. Department of Agriculture and the Corps of Engineers since 1968. The State of Florida has probably spent in excess of $10 million for white amur research at one level or another--grass carp research. I think we all agree that the white amur will control aquatic weeds. We have established that 20 lb of fish per weeded acre is too high. Of course, we have not definitely established what a weeded acre is, and some of our research coming up next year will be to determine what the actual biomass is; then the criterion will be pounds of fish per pounds of biomass of weeds. However, with 20 lb of fish per acre you get overcontrol; and 2 lb of fish, standing crop per acre, is too low. So we've got a slide rule. We need to determine the coarse adjustment, the reostat, and decide how we are going to be able to vary it from one point to the other.

Of all the studies that have been done in Florida, there are a number of parameters that have never been monitored closely at the State

level. These include the impact on native fish and the direct impact on aquatic vegetation, primarily native nontarget species. In Florida, the study lakes are located in central and south Florida; they will be set up on a 3-year program in which there will be integrated aquatic plant management. A number of the lakes will be treated with herbicides and stocked with fish, and a number will be stocked first with fish and then treated with herbicides. The only two parameters that the State will be monitoring will be the impact of the grass carp on native fish and the impact of the grass carp on the native plants. In other words, we're going from the point of enough basic research into the operational management within the state. That decision was made just recently.

To sum it all up, the grass carp shows a lot of potential within the United States, and I think we'll probably see research and management continue with the State of Florida converting out of the basic research phase and into the operational management phase with the grass carp. I also think that the controversy over the white amur will go on for a number of years. Since the "Florida Experience" probably will not provide the type of discriminating information that you as states and as various regional outfits are going to need to determine a go/no-go situation, you will have to make these decisions on the local level. Most of the Florida information that will be derived will be in terms of guidelines, guidelines that give some basic information from which to develop site-specific plans of operation for the use of the white amur within your state or region.

STATE OF THE ART--MECHANICAL CONTROL

by

Perry A. Smith

Mechanical harvesting, as far as a study of the Corps of Engineers documented data reveals, has been around about 3 years now, 1976, 1977, and 1978. In 1976 we tried off-the-shelf equipment, but we failed to find what we needed. We decided engineering and research data were needed to tell us what to do next. In 1977 and early 1978 we collected these engineering data, and we are now in the process of analyzing these data. We plan to publish a report on our finding that, hopefully, will enlighten us all.

There are two problems connected with mechanical harvesting: floating aquatics and submerged plants.

STATE OF THE ART--MECHANICAL CONTROL

Control of Floating Aquatics

by

William E. Thompson

In the New Orleans District we have a long history of mechanical control of aquatic weeds, but we don't have a very recent history of control by mechanical means. I will discuss some of the things that have been done in the past and some of the things that are presently available in the way of mechanical control systems of the aquatic plants.

The earliest control of aquatic plants by the Corps of Engineers occurred around 1900 on waterhyacinths. After a study was conducted, the decision was made that the best way to control the plant was by mechanical control. The Corps felt that even prior to 1900 there were some bad experiences with biological control so they tried a number of chemical controls which were unsuccessful. They then reached a decision that the best method of control would be mechanical. They built a crusher boat in the New Orleans area and used it to crush waterhyacinth for about 2 years, after which they decided that it was too slow and was never going to catch up with the problem. They then went to a chemical control using sodium arsenite, but by the 1930's it was decided that sodium arsenite was too dangerous, so they went back to mechanical control. After the development of 2,4-D in the middle to late 1940's, they decided chemical control was still the best, most effective means available. To some extent this holds true, to some extent, perhaps not. There are other values that have to be attached from chemical control leaving some of the nutrients in the water; there are advantages and disadvantages in both directions.

One of the crusher boats that was used in New Orleans picked up the plants on a conveyor, crushed them through rollers, and then dumped the residue overboard. This really didn't remove the plants from the waterway.

Another mechanical system that was used in the Jacksonville District was simply a conveyor that picks the plants up and dumps them out to the

side to get them out of the waterway. A number of these machines have been built and one was used in the New Orleans District.

To some extent we are still involved in similar types of control. A small local conveyor was built in the Houma area and used in Bayou Black which happens to be a drinking water reservoir. However, I think the plants can grow a little faster than they could be picked up with that conveyor. This conveyor system had a handling problem. They'd pick the plants up and dump them in either of two pontoons; they then had to pick them up with a sling and a dragline, resulting in a very slow and tedious process.

A harvester system was used in Punta Gorda, Florida, that had another problem. The wind changed and the plants all floated to the other side of the lake leaving the conveyor sitting there. They had to go out and lasso the plants with air boats and bring them to the conveyor, delaying things a little bit.

A large conveyor system was built by the Department of Natural Resources and used in the St. Johns River in Florida. It wasn't used very long, however. Another conveyor system was built for the National Aeronautics and Space Administration (NASA) at Bay St. Louis, Mississippi, to use waterhyacinths to purify sewage affluent. In purifying the sewage affluent they decided they needed to harvest the waterhyacinths; they have been using this procedure successfully at Bay St. Louis.

One of the earliest boom systems used consisted of a boom across the waterway to catch the waterhyacinths. Once caught on the cable boom, the waterhyacinths were towed by pulling the rope over to the bank and were then pushed out with a bulldozer; this procedure was slow. We're still using somewhat similar tactics with a dragline on a barge; this method has been used in one of the oil exploration and production canals just west of New Orleans. The Amoco Oil Company used this method to take waterhyacinth out of one of the canals; it was very expensive and very slow.

Another system used south of New Orleans in Venice, Louisiana, combined a boom to confine the waterhyacinths and a marsh buggy crane, which is a floating crane, to pick the waterhyacinths up and dump them

into dump trucks on the bank; again, this is slow. They also used airboats to service the boom, keep the plants corralled in the boom, and move the plants to the dragline.

Another boom system used in the Panama Canal is a system for containing the plants so that the plants can be removed by a large bucket with a slack-line system. It's still in use in the Panama Canal Zone, has been for a long time, and probably will continue to be because it is very effective. It's an old method, but it works.

One of the earliest mechanical cutting boats was used in the Jacksonville District. It's a little boat with some vertical saws across the front. The object is just to run through the plants and chop them up in such little pieces that they can't regrow. We had things bigger and better in Louisiana, a bigger boat built to do the same thing. The vertical saws were closely spaced together to cut their way through the plants. Unfortunately, it's necessary to run back and forth over the plants about four times before you cut them up into small enough pieces. This slows you down a little bit. If you get a big enough boat, for example one that will cut a 40-ft swath, you can cut more efficiently.

Sometimes the natives come up with ideas, such as the trenaus cutter. The trenaus is simply a small trench that is used by fur trappers and fishermen to get from one location to another. They just cut through the marsh. There are two blades and a water exchange for cooling water for the engine. It's surprising how much this particular vessel looks like Lentana Boat Company's cookie cutter, used to chop vegetation. The cookie cutter has vertical blades on the front with which to chop through waterhyacinths or any other immersed vegetation, making its own flotation channel. The original vehicle had a lot of blades on it; but after some work, they found out that they didn't need quite that many blades to do the job, so it was modified. It's simply a method for chopping the plants up that's propelled by the pitch on the blades.

The Aquamarine Corporation's harvester Aquatrio has cutter bars across the sides and across the bottom so that it can cut a path, pick the plants up, and deposit them into a holding area. From that holding

area they can be transferred via a second piece of equipment, the transporter. The cutter can continue working while the transporter moves back and forth with loads of vegetation. There is still a third piece of equipment, the shore conveyor, which picks the plants up and either dumps them into a pile or dumps them into a dump truck and disposes of them onshore. This piece of equipment probably is the most widely used piece of mechanical equipment anywhere in the country.

The waterbug is another mechanical cutter used to cut a pathway through either submersed or immersed vegetation. It will cut through cattails, cutgrass, or anything similar; it draws very little water.

A rubber-tired piece of equipment manufactured in Denmark has recently been brought into this country by the Arondo Corporation. The equipment comes with a number of different attachments. One version is the "Tortoise," which is the four-wheeled vehicle with a rake. The rake can be used to either place the vegetation ahead of the machine at a selected location or the rake can be used to pick up the plants and transfer them into the bed located behind the operator. The machine can also be equipped with a double-action cutter bar to cut vegetation hydraulically. A reed harvester can also be attached that cuts the weeds or grass, binds it, and stacks it into the same bed on the dock. The bed of the Tortoise lifts, allowing the operator to take the plants over to the bank and dump them.

The Mudcat, a small suction dredge, has been used on some submersed plants with very little success. It has not been used to date on any surface or emerged vegetation. However, an industrial vacuum system has been used in a lagoon in Houma, Louisiana, to pick the plants up from the water and eliminate some of the snags and underwater obstruction. It worked out quite well causing no problems in picking up the plants. The Tortoise pushed the plants up to the vacuum and the vacuum picked the plants up and dischaged them into the truck. This system may show some promise. A smaller machine was also tried in central Louisiana that cut the plants to some extent and blew them out a discharge tube. This may be able to be used in connection with the Tortoise to actually vacuum the plants off the surface of the water.

STATE OF THE ART--MECHANICAL CONTROL

Control of Submersed Plants

by

Richard Koegel

I would like to talk a little about the capabilities of existing mechanical harvesting equipment. Five years ago, we plotted the amount of acres per hour that could be harvested with conventional type harvesters versus plant density. As you might expect, as the plant density increased, the number of acres per hour handled went down. Factors other than the plant density enter into mechanical capability, such as wind and wave action, the particular operator, the amount of incentive the operator has, etc. This latter factor is not a small consideration.

Another method of determining capability is by plotting the harvest rate in pounds per hour harvested versus plant density per acre. Again, as you might expect, as plant density goes up, you are able to harvest more pounds per hour. However, most people are more interested in harvesting acres per hour rather than pounds per hour. It's the coverage in the area that's of interest to many people. Generally, something on the order of 0.4 or 0.5 acres per hour might be an average figure that you would expect to attain with conventional type harvesters.

It is not possible to harvest continuously as was verified by checking data from a Dane County, Wisconsin, operation that was probably, at that time, the largest existing submersed plant harvesting operation. There were certain factors that did not allow them to use the harvester all the time. In their case, they spent a lot of time in 1972 moving from lake to lake in response to political pressure.

Harvesting underwater in certain lakes entails a certain element of risk in the form of underwater obstacles that the harvester can run into. This can cause downtime which varies from year to year. Some downtime could be eliminated by good preventative maintenance.

Considering money, the cost broke down as one fourth of the costs spent to defray the investments in machinery and one fourth spent as the actual operating costs. In the Dane County case, they spent a lot of

money on repair, overhaul, and modification due to some very extensive modifications they did to some of the equipment. This case is probably not typical of what you'd expect to find in most harvesting operations.

The harvester used in the Dane County operation that was modified was a system with a conveyor down into the water with a reciprocating type cutter blade at the very bottom of the conveyor bringing the material up. This particular harvester also has a forage chopper on the deck. The material is run through this forage chopper, cut up finely, and placed in an operating transport barge that is towed behind the harvester at all times. An inclined conveyor brings the chopped material into this transport barge which has a self-unloading type of agricultural forage box on the deck enabling it to be automatically unloaded upon reaching shore. As soon as the barge is filled, it can be replaced by another similar type transport barge and the harvester could operate almost continuously. In some cases the harvester does its own transporting, resulting in some nonproductive time. The percentage of time spent in transport depends a great deal on the lake configuration and the number of access points available for getting the material off the lake.

Before unchopped material from harvesters is trucked away for use or disposal, it is run through an agricultural type forage chopper to reduce the bulk of the material to make subsequent handling easier. A lot of the material is made available to local residents who use it on their gardens, flower beds, etc.

As mentioned earlier, conventional harvesters tend to operate at a slow half an acre an hour. There are a couple of ways to harvest at a higher rate: one is to increase the width of the swath, the other is to increase the forward speed. An attachment that was tested by Dane County was placed ahead of a conventional harvester. The attachment was a set of two inclined arms that formed a "V" allowing the operators to sweep a swath three times greater than before. The self-contained attachment had its own flotation and its own power units so it was merely pushing ahead of a conventional harvester. The idea here is to have a separate rather high-speed cutter that goes ahead of the harvester, does the

cutting, and allows the material to float up on the surface. However, in tests of this machine it was also found that operating these teeth at fairly high speeds (the teeth travel along the arms from the outer forward edges back to the vertex of the "V" carrying material and concentrating it as it goes back) resulted in flailing off the material without previous cutting. The intent, however, was to go out ahead, cut, and then pick up the floating material.

This device also does not have any structure protruding very deeply down into the water, so you can not only increase your width by a factor of three, but you can probably increase your forward speed by a factor approximately of two. So you've gained by a factor of five or six to one. This is, of course, presuming that the harvester and the equipment on the deck of the harvester can handle the plants coming in at these greater rates. The arms travel outward, inclined out of the water and then back toward the harvester dipped down into the water so they contact and concentrate plant material as the harvester moves forward through the water.

One cutting machine capable of cutting a swath 20 ft wide has as its power unit a conventional agricultural tractor. This motor powers the cutter as well as the propulsion unit, which consists of paddle wheels attached to extended rear axles. This procedure allows the use of a mass-produced item as the power unit, resulting in some economy. The lack of mass-produced units previously has been a handicap in mechanical harvesting equipment; since the equipment was built on a very small scale, that is very few units built per year, the benefits of mass production have never been able to be applied to mechanical harvesting. Consequently, the unit costs tend to run high compared to comparable types of agricultural or automotive machinery that can be mass produced.

The raking and pickup unit designed to follow the cutter has a sweep width of 28 ft. The unit brings the material into about a 4-ft width by means of rotating raking wheels that are somewhat inclined to the water. The tines at the front ends of the wheels dip into the water, are brought around from the outboard side to the center, and the material can then be picked up by the conveyor which is just slightly dipped down

into the water. Again, an agricultural tractor is used as the power unit. The unit includes a grinding machine, or a milling machine, that reduces the harvested plant material to a slurry and has a tank barge that can be pulled behind. This tank barge receives slurry coming off the grinding machine and transports it to shore. The slurry is pumped finally from the tank barge onto a tank truck for transport away.

A slightly different attack of the harvesting used in central Wisconsin is characterized as being a low-capital, somewhat more labor-intensive system. In a small Wisconsin lake a small cutter with a capability of about an acre and a half per hour was used. It is a relatively inexpensive machine that makes use of currents through the lake plus the predominating winds to bring the plant material into certain bays. A vertical curtain or net is put up to keep the material from going onto land. When a sufficient amount of material has collected on the net, the net is towed around into a loop; a boat pulls one end of the netting around, concentrating the material within the net. The net is pulled into a relatively small loop and the material is carried up a conveyor. Manual assistance is needed to help the material along. The material tends to interlock and will not feed freely onto the conveyor; however, this assistance is not a drudgery type work. Instead, it's a raking type of activity as opposed to a lifting and throwing activity, which would be necessary were it not for the conveyor. It at least uses the human labor fairly efficiently. The final component in the harvesting operation is an agricultural type of elevator and a small conveyor that dips down into the water and loads into the agricultural conveyor, which in turn loads into a municipal type waste disposal or packer truck. Since the Wisconsin project was completely a civic type operation manned by volunteers who showed up once a week, they were able to get the packer truck evenings from the small town where the project took place. That worked out fairly well in that they got some volume reduction and some expression of moisture as this packer truck packed this material in. This was carted away to be used as a soil conditioner, or added to agricultural lands.

Another type of stationary takeout point is used on the Fox River system, an impoundment called Buffalo Lake. A barrier goes out across the channel above the dam that creates the lake. The barrier dips down into the water to a depth of about 2 ft and impedes floating material that comes down from the lake from flowing over the dam. The plant material works along the barrier to the downstream side where a takeout device is located. The device in turn dumps the material onto an agricultural conveyor which carries it up onto a truck. The Property Owners Association that runs this removal system has rather limited funding, so they use a relatively simple system. The takeout device, a raking device as we call it, is a slatted incline plane dipping down into the water with tines that drag the plant material up the incline and then onto the apron of the agricultural conveyor. In some cases an assist of water jets is used to move the material along the channel barrier to bring the material into the takeout device.

Finally, monetary savings in handling and transportation can be realized by pressing out excess liquid and compacting the material. An example of a press that can be used for this type of operation is known as an E-press or double cone press. Two opposing cones with perforated spaces are used, and the material is packed between these cones at the widest spacing between them. The press rotates half a revolution with the cones to the narrowest point past the neck and, in the process, the water is squeezed out. Commercial presses are generally not available in a size consistent with aquatic plant operation needs, or what you would like for aquatic plant operations. This particular press, however, handles roughly 20 tons per hour of wet material. It, therefore, begins to approach the size of pressing equipment needed in an aquatic plant operation and could be scaled up without too much trouble.

STATE OF THE ART--INTEGRATED CONTROL

Chemical/Biological/Mechanical Combinations

by

E. E. Addor

A discussion of state of the art for integrated control may be brief or long, but will depend upon how we define integrated control and what projects we have going that fit under that definition. I want to identify perhaps four relations that may be included under this concept. The first one would be the use of two or more kinds of organisms simultaneously to attack a plant population. The second one would be using behavior modifying chemicals to aggravate an attack by a consumer or pathogenic organism. The third one would be the use of machines, environmental manipulation, chemicals, or other means, to remove initial biomass followed by the use of other machines, mechanical devices, chemicals, or organisms to maintain the weed population at the reduced level. This can be called initial reduction followed by maintenance. The fourth one would be the application of one method of control at one place on the hydro system combined with the use of another method at some other place.

Until recently the term integrated control was used to include application of insects and pathogens in combination, that is, integrating their life cycles, implying that the population of insects and the population of pathogens would establish their regimens in response to constraints imposed, one upon the other. It is implicit in this concept that the two kinds of organisms would indeed act synergistically to impose a greater stress on the plants than either kind of organism alone.

However, it is not always the case that just because you have two organisms, they will work synergistically. It appears, upon consideration, more realistic to consider the approach of mixed organisms to be biological control with multiple agents. It is entirely possible, and apparently is the case with some of the organisms presently under trial with waterhyacinths, that a repulsion or exclusion factor may operate so that the presence of one kind of organism will, in a sense, deny the

presence of the other, whether this is insect to insect, pathogen to pathogen, or pathogen to insect.

The suggestion that chemicals in dilute concentrations may be applied to modify the behavior of insects or pathogens is, at present, far more advanced for insects than for pathogens, but the principles are the same. For insects, such chemicals include, in a broad sense, two classes. There are the sex attractants, called pheromones, which stimulate sexual behavior causing the insect populations to increase at a greater rate than it otherwise would. There are also kairomones, which include any of the various chemicals produced by the plant itself, for example, the turpenoids, which attract the insect to the plant and stimulate feeding behavior by the insect. To the best of my knowledge, little has been done with the sex attractants in relation to biological weed control. But it so happens that very dilute concentrations of certain herbicides, 2,4-D is one of these, will function as a kairomone for the waterhyacinth weevil.

The chemistry of this phenomenon is not known, whether 2,4-D itself attracts the insects or whether the physiological response of the plant to the herbicide includes the production of a kairomone. As with biological control with mixed agents, the philosophical question can be legitimately asked whether behavior modification of an insect or pathogen by artificial stimulation is properly included under the research area called integrated control, or is this simply another aspect of biological control?

The objective of this kind of control is not to kill the plants or even to stress them necessarily, except to the extent that the stress may change their physiology in such a way as to aggravate the attack by the controlling organism. Rather, the objective is the aggravated attack by the controlling organisms and the rationale as opposed to a hit-or-miss application of this approach depends upon an understanding of the physiological interactions between the plant, the attacking organisms, and their respective environments.

The last two relationships (environmental manipulation and the application of one method of control at one place and another method

at another place), I think, may truly and unquestionably be called integrated control. There is some question in my mind, however, whether they are sufficiently distinct as to rate a distinct research area. Again, on a philosophical plane, which is probably where the concept of research area as a program management tool actually resides, it seems to me that these approaches are basically strategies for operational deployment of whatever tactical equipment we have at our disposal for use in a given situation.

The point is, that with neither of these two approaches is it necessary, with perhaps a few possible exceptions, to modify one method of control in order to successfully apply the other. For example, we may find it useful to draw down the reservoir in order to apply soil incorporative herbicides or to place screens, and it may be most effective to do this at a time when the plants will not respond to the drawdown by mass production of regenerative organs, or at a season when desiccation of the soil will ease the soil treatment. I predict that, in order to rationalize this kind of strategy, the plant behavior will have to be well understood as a result of research on plant behavior. The methods of soil treatment will also have to be well understood as a result of research on treatment methods. These are independent lines of research, the integration comes in their deployment.

The essential difference between the two approaches, as I have defined them, is that one involves different methods of control applied sequentially at one place on the hydro system, while the other involves different methods applied at different places on the hydro system. And these may either be sequential or simultaneous in both time or space.

An example of the application of the latter relation would be an effective part-time biological control for a weed that, under ordinary circumstances, would present no problem, but sometimes under certain weather conditions, for example, the weeds would outgrow the control agent's effectiveness and would require temporary alternative treatment. Specifically, for example, suppose the organisms we now have for control of waterhyacinths prove to be effective except in the backwater swamp areas where they are unable to complete their life cycle because the

plants at certain times of the year are rooted on mud rather than free floating. Understanding that relationship requires understanding the life cycles of the organisms. Again, this is a problem in biological control, or biology of the organisms at least.

During periods of heavy rainfall, that is, during periods of temporary high water, some of these plants will break loose and drift downstream where they may pile up against obstructions such as bridge pilings, docks, pump intakes, etc. In that situation, they will present a temporary nuisance. This nuisance is temporary because if we do nothing, the control organisms would eventually reduce them again to acceptable levels. It is, however, still a nuisance in the sense that in the meantime we would be deprived of our preferred use of the water. In such a situation, I can foresee that a mechanical device, such as an inexpensive dragline permanently installed, might be used at that location on the hydro system and thus integrate mechanical control with biological control. Again, I submit that the research for both of these methods is quite independent, the only integration that is required is in assessing the problem, which now comes under the heading of problem assessment, and then rationalizing the deployment strategy.

I think that the state of the art may be well along in integrating all the present control methods purely by fiat because we're solving problems here and there in the field, more or less, and every partial solution to one problem in the field, by nature of the behavior of these weeds, affects a problem elsewhere in the field. Except for those that I called biological control by multiple agents and behavior modification, I know of no cases of environmental manipulation or the application of one control method at one place and another method at another place where we are consciously and deliberately rationalizing deployment strategies. Whether we should be doing this or not will be taken up later in this meeting.

STATE OF THE ART--INTEGRATED CONTROL

Operational Management of Eurasian Watermilfoil in British Columbia, Canada

by

Peter R. Newroth

I want to quickly go through the things that have been done in the last 6 years of the Canadian program. Basically, my talk will center on the following areas: first, an introduction on the responsibilities and policy, second, a review of some of the components of our program that will not be discussed later, namely, research; mapping, surveying, and documentation throughout British Columbia of aquatic plants in general; the quarantine work that was done this year and some proposals for the future; and a listing of the conventional technologies that we've looked at. Finally, I want to made a few comments about our future plans. Our main topic is that we don't want Eurasian watermilfoil; but I think we've got it forever now. Initially our problem was a very small one and at that time eradication was a worthwhile goal in the overview. Now, however, I think we must abandon that except perhaps on a very localized basis in isolated bodies of water.

The involvement of the Water Investigations Branch, which is one component of the Ministry of Environments in British Columbia, began around the beginning of this decade and since 1971 has assessed a number of aquatic nuisance situations and documented the spread and proliferation of a particularly troublesome plant, Eurasian watermilfoil. This Branch today is becoming increasingly involved with the environmental problems caused by the presence of this nuisance species.

Eurasian watermilfoil has been viewed as a threat to the traditional values and the utilization of the waters in British Columbia. This policy of management of the plant as a severe environmental problem has been developed through experience in documenting the spread of the plant to occupy between 1500 and 2000 acres of the shoreline in Okanagan Basin of British Columbia and to a number of small water bodies adjacent to the City of Vancouver.

Of course, other people have had experience with Eurasian water-milfoil, particularly Ontario, the Tennessee Valley, and Florida.

Our agency is obliged to respond to requests persistent from local authorities, for example, municipalities. Our reaction to these requests is usually in the form of technical advice and recommendations, although, in some cases, cost-sharing arrangements and direct implementation activities have been undertaken. With local authorities and in cooperation with other agencies, usually Federal and provincial government, we have attempted to seek practical cost-effective and environmentally safe solutions to problems. We have been obliged to develop an in-house expertise in many areas of aquatic plant management.

In the research area, we've been fortunate in our program to have the resources to explore a number of general approaches which should yield a better understanding of the biological and ecological characteristics of Eurasian watermilfoil, specifically in British Columbia. This approach, we hope, will reduce the chance of overlooking any long-term management alternatives.

I will now present a very superficial listing of the categories in general terms of the research that has been followed in our programs to date. Of course, we have been subject to numerous literature reviews, particularly we have looked at potential biological control agents and areas of possible utilization of Eurasian watermilfoil.

In the more pure botanical area, we've done considerable amounts of work with identification. In the initial years, we weren't sure of the species of plant that we had and many times the essential taxonomic information is just not thoroughly developed before work is begun on a problem.

One important area, of course, is that the identification of the species be clear. This has ramifications to biological control if, for example, Eurasian watermilfoil in North America happens to be a different organism, in some genetic way or otherwise, than the European species. There's not much point in going to Europe and looking for biological control agents if they are not the same organism. I'm a little bit unsure at the present time whether we are talking about the same organism

in the true sense, from Europe and North America. We're hoping to do some work on that, and I'm sure others of you would be concerned about this.

In the general area of ecological studies, we have looked at such things as macrophyte composition and abundance; we've looked at seasonal growth studies to determine the period of growth, flowering, and fragmentation. We have 10 sites under study at the present time where we've looked at viability of fragments, particularly using mechanical methods; we're concerned about the escaping fragments, whether they will cause problems downstream. We're also looking at the evaluation of fragment dispersal as a mechanism for extension of the growth of the plant. We're looking at seed germination, trying to determine the effects of waterfowl taking the seeds and then passing them through the digestive system. Preliminary information indicates that there is an increased viability of seeds after passage through a duck. We have studied the effects of freezing on seeds, and we've looked at repetitive harvesting, looking at differential growth rates and different cutting depths, etc.

We are also looking at possible biological control. We found one lake in British Columbia this summer in which a population of Myriophyllum spicatum had been suppressed by a snail identified as a Physa species. We haven't found the specific epithet yet. Of course, whether or not this snail can be practically applied has not been determined; we're concerned that there may be conflicts because of swimmer's itch which may be transferred by the snail.

The habitat and nutritional studies have been very important also because we want to be sure that we know whether the growth rate of watermilfoil is due to stream-borne dissolved nutrients or whether it was hydrosoils in a lake. We also need to determine what the stimulating factors are that encourage this plant to grow; this, of course, is necessary for long-term management.

Our earlier surveys, in 1972, with the simple parameters such as organic and nitrogen content of the soil, found very basically that the presence of Myriophyllum spicatum grew very independently on such parameters as size and sediment chemistry.

Sediments that prove to be very important as a means of nutrient source to this plant have also been studied; we have continued our work on interstitial water chemistry to evaluate the available nutrients that would stimulate the species. We've tried to look at the sediment and plant tissue nutrients to evaluate the possible limiting factors that could give us a management long-term goal. Are there lakes which the sediments depauperate in certain nutrients so that you don't have to worry about the plants becoming established? This is important in an area where a plant is newly introduced and you are concerned about how much investment to put into long-term control. It you have it localized in a few small areas, you would like to know how far it can spread.

We have tried to look at the effects of sodium chloride and lime as hydrosoil amendments and tried to find out the effects pH change might have to either limit nutrient uptakes or have a direct effect on the plant physiology.

In the area of surveying, mapping, and documentation, we have attempted to be systematic in surveying aquatic plant problems throughout British Columbia which is very critical for baseline information. The most dramatic result has been the demonstration of the expansion of the Eurasian watermilfoil in British Columbia; these detailed surveys that have been made, particularly since 1975, are very valuable. The most recent surveys this summer showed continuing expansion of the plant to occupy new habitats, especially in the southern end of the Okanagan Valley, and, most important to people in Washington, in the northern end of Osoyoos Lake.

Throughout British Columbia we've surveyed about 500 lakes for the species and we are updating our surveying on a day-to-day basis. We have now identified seven species of Myriophyllum in the Province and the detailed collections of the species in this genus are being collated properly and put into an herbarium. The findings of a lot of these surveys will result in a handbook of British Columbia aquatic plants which is now in a draft form; we hope to be able to circulate it to interested parties next year.

One of the more interesting areas we have studied involves the

possibility of a quarantine program. This summer we had about 90 summer students hired with funds from the Ministry of Labor Youth Employment Program; the main goals of the quarantine program were to assess the potential of the spread of Eurasian watermilfoil by boating; prevent the transfer of the plant; and provide a vehicle for good public relations.

Preventing the transfer of this plant wherever possible from infested to uninfested areas is accomplished by surveillance in those major areas of British Columbia, primarily in the Okanagan region, but also with some efforts in the Shuswap north of the Okanagan and in the Copus Lake area.

Through public relations we communicated the concerns of the program to more people than any other method achieved so far. We have about 20,000 forms that are being subjected to a computer analysis right now. The forms are more or less a questionnaire that was filled out by our staff at the boat launch ramps; because of the wide acceptability of the program and the possibility that boating activity really is a significant mode of transfer of this plant, we're looking into the prospect of an additional quarantine program next year, possibly legislation to enforce it. At the present time there is no legislation that we can use to really pull people off the highways if they're moving this plant around.

The main control technologies consist of ten categories. More about half of these categories will be mentioned later. We have dedicated a certain amount of effort to the study of eutrophication control and erosion control. We've also looked at lake drawdown, the possibility of biological control agents, opaque bottom barrier membranes, several types of dredging activity, and harvesting activity. Rototilling, the use of water jet manifolds, hydraulic washing, the use of fragment barriers to contain the plants, and the use of a number of herbicides have all been given a very careful review as part of our program.

For the future, we're trying to be as careful as possible with our planning. There are so many avenues that one can be led into that are blind alleys; we've come to a point now where we have certain objectives that are more clear-cut, I suppose, but the problem has grown while we've been watching it. In Okanagan, for example, there are 1500 acres

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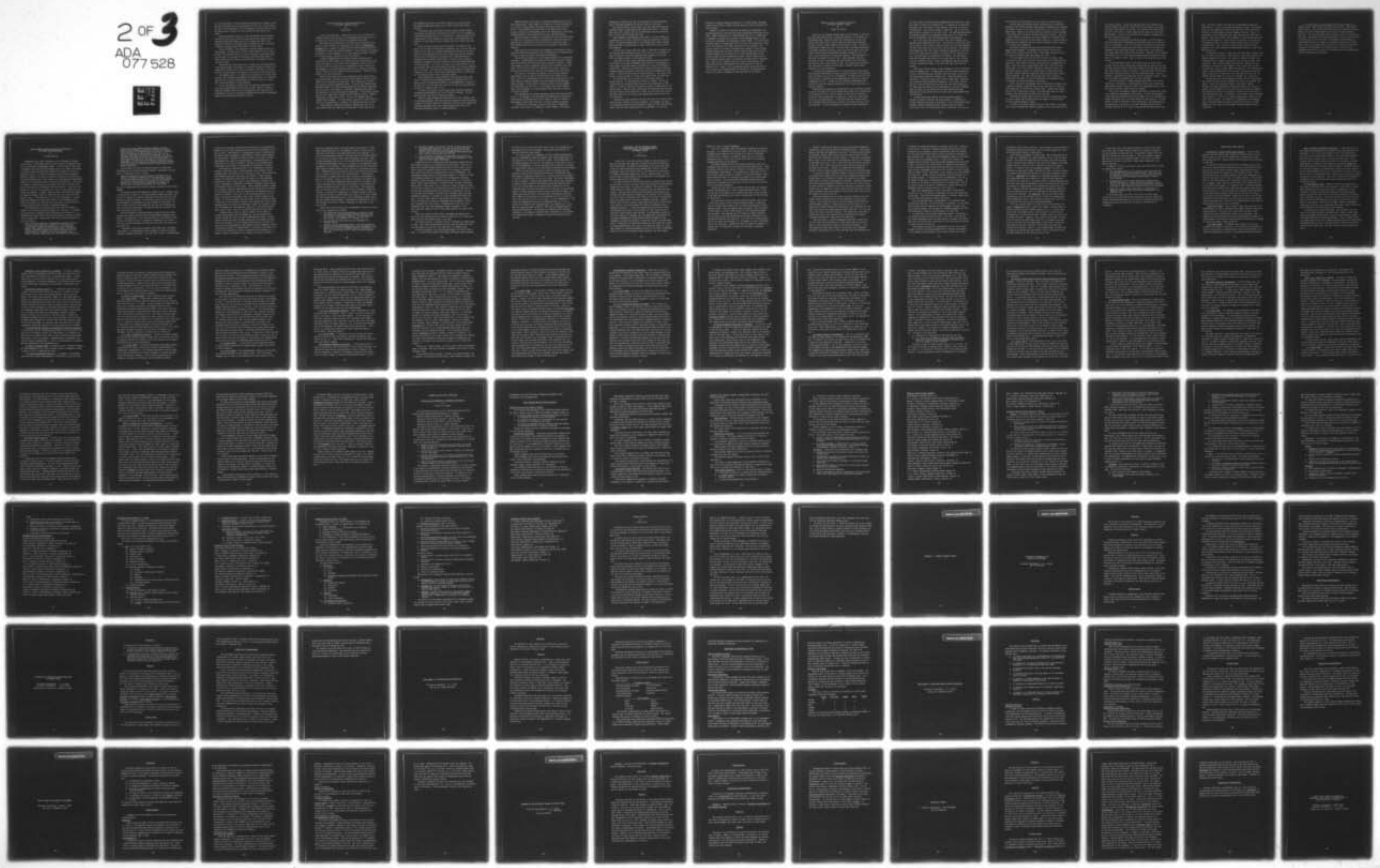

or so of dense weeds. We have conflicts with those in a number of areas and we've now moved into an operational mode with a lot of those areas. Of course we're undergoing a lot of evaluation of the work that has been done and we have a backlog of reports which will keep us busy all winter.

The most profitable areas for future development will be pursued this winter and early in the next season and we are planning a major operational mode next summer also; we are hoping next year we can continue to contain the problem wherever possible and also to continue to reduce the impacts where they affect the public most.

We are, therefore, very responsive to public complaint about the weed problem. We realize that we can't tackle 2000 acres all at once. We have to be selective which, I think, is going to be the major theme for next year; we're going to selectively pick those lakes where we think we have the best chance of success and put everything we've got into those areas.

The really long-term plan will be to reduce all the populations to a size small enough to be handled by an annual maintenance program that hopefully the Province won't have to undertake. Hopefully, it will be done by the local agencies who asked us to be there in the first place.

Our immediate goal is to complete our evaluation of the 1978 trials with the 2,4-D chemical and mechanical technologies and, as I mentioned, catch up with our report documentation in order to allow us to share with you the information we have gathered.

We are also hoping to improve upon the existing technologies and to put our resources where we will have the best chance of success. I think the speakers which will follow immediately will illustrate the development of the most promising and immediately available technologies, namely, the mechanical and chemical controls.

Mechanical Control of Eurasian Watermilfoil
in British Columbia, Canada
by
Greg Armour

By way of introduction, I would like to let all of you who aren't familiar with the exact location of the Okanagan Valley know that it is in Canada, not far north of Seattle and somewhat more inland.

The lakes we are dealing with, actually 6 main stem lakes in the system, are all infested, to some degree, at present by Myriophyllum spicatum, most of them to the degree now that water-based activity and recreational activity are severely hampered. Since tourism is the number one industry in the Okanagan, it is a very disturbing prospect to most of the local people, especially on the Yacht Basin.

A popular swimming beach on Kelowna foreshore experiences an accumulation of plant debris every spring after the weeds break off and float up on shore. We have been using an amphibious track vehicle to push up the mud, but since this is a multimillion dollar industry for the Okanagan it is not particularly beneficial for tourism or property values to have 2-1/2 ft of black mud on the foreshore. Therefore, this method is not very satisfactory.

Back in 1972, when it was first recognized that an aquatic macrophyte could become a problem, we went for the available solution, which seemed to us was going to do some good. That solution was a harvesting operation using an Aquamarine device. We also tried several other methods on some of the smaller weed patches that had become established with the idea in these cases of, hopefully, eliminating the spread of the population, if not eliminating it permanently. We installed a bottom barrier over a small 100-ft-square patch of weeds in a lake. A Mudcat dredge was also experimented with. An arm of an Okanagan lake was cleared with the Mudcat. It proved rather costly and it didn't take too long for the watermilfoil to reinfest, one growing season did the job.

Other methods attempted were aimed at removing the root of the plant rather than just cosmetically harvesting; we again made use of

the Aquamarine harvester and attached a water jet to the front end. This method showed some promise, but it wasn't nearly 100 percent effective.

The approach that we decided to pursue entailed taking a garden tractor into the lake and rototilling the bottom. We're in somewhat of a different situation than a lot of locations, I think, because we have a sandy bottom, fairly regular in nature; once you document where the drop-off is, you're fairly safe in taking this type of device into the water.

Since this method proved fairly successful, we decided to move deeper into the lake by modifying the bombardier cab. We built the side walls up 48 in. and put a standard agricultural rotovator on the back. As part of the program we did not want to spread the weed any further, since we were still dealing with patches that, although they were expanding, were isolated to some extent. We had to have a means of keeping the fragments that were rototilled up from spreading downstream to other locations. To do this, we built a very simple barrier out of nylon anchovy seine with foam flotation attached to it that was deployed out in the water. This was about 95 percent successful in keeping the fragments in the area. Since we had no mechanical device to pick them up, we allowed the wind to blow the plants ashore.

Since watermilfoil causes problems in water depths greater than 48 in., we had to move to something capable of operating up to 15 ft; again we used the Aquamarine harvester by attackinganother rotovator to the back of it on 14-ft arms that would tip it down and allow effective rotation to a depth of about 13 ft.

In 1976, we initiated a fairly large-scale harvesting operation encompassing approximately 110 acres of Kelowna foreshore. The job was fairly well done and did show some promise.

There are some problems associated with use of the rotovator, one of them being guidance. When you lower the rotovator to the lake bottom, although it's fairly regular as I mentioned, there are still ripples and obstacles; whichever end of the rotovator hits first, that's the direction the machine turns in, causing problems.

Another problem is that after a rotovation operation there will be some material left. Even though it's uprooted it is still possible for it to retain enough sediment and organic material to keep it on the bottom. That, combined with misses due to the human error of the operator, results in reinfestation, and we are talking about a much more expensive method of weed removal now that just plain harvesting.

Another problem is caused by the existence of some rocky areas where we cannot run a rototiller without replacing the teeth every time, and unfortunately, watermilfoil picks just about any location to grow. Fast-flowing areas as well as very rocky areas would be impossible to rotovate.

Plant material left behind by the machinery and reproductive fragments from untreated populations cause reinfestation of the Kelowna area in about 2 years, and that's 100 percent reinfestation.

The monitoring component of our program assessed all our mechanical treatments. Determinations were made of shoot density and root biomass based on extensive field operations before and after treatment. Longer term changes in species composition and macrophyte diversity were also noted. We've had the reports in preparation for about a year and a half, and they should be out soon and will document this fairly well.

Our efforts to eliminate the spread of the weed were somewhat unsuccessful; year by year the population got more and more out of hand. By 1977, we recognized the fact that we were going to have to use other types of cosmetic treatment that were capable of dealing with larger acreages. We also built a second rotovator that was somewhat more simplified than the first. It was bigger, had a wider heading swath, and was powered by a single engine rather than the two used on the previous machine.

We experimented with another Aquamarine device that incorporated an 8-ft cut. We thought it was worthwhile experimenting with cutting the plants deeper and perhaps twice in one season to see if it would do some damage to them rather than just a strictly cosmetic operation.

In addition, we continued to pursue other types of mechanical treatment, one of which is a hydraulic cutter's dredge. The obvious

limitations to that are its cost, the necessity for spoils disposal which is the major problem, and the fact that it's very slow.

We tried the garden tractor again, the idea being that since the rotovator worked, an agricultural disc might work better. It worked quite well, but it didn't work to the same degree that the rotovators have, so we're still sticking with that.

Lake drawdown in the Okanagan would seem to be a very simple way of getting rid of at least a portion of our weed population. Unfortunately, the physical limitations in the Okanagan would require several million dollars of modifications to enable achievement of any success with drawdown.

One location in Skaha Lake just south of Penticton is possibly the only location where drawdown has any effect at all; it is possible to limit 20 percent of the weed population with drawdown in that lake. We'll be making an effort at that again this year.

Since some of these large established populations of watermilfoil were acting as a source of fragments that could drift downstream and infest some of our other lakes, we decided we'd better do something to prevent that. Therefore, we instituted a system of barriers located at strategic points to prevent or limit the weed from spreading into other lakes. In 1978 there were seven of these structures. The typical river barrier is held in place by a cable and pilings driven on either side.

We used another type of barrier to cross Osoyoos Lake in a shallow portion. It stretched about 1500 ft in length. This is the closest point to the United States that we've been involved in; hopefully, it's been of some help in protecting areas of Osoyoos Lake in the United States. There are some difficulties in installing these barriers. You have to hire a pile driver and a crane, and since they don't like to run their crane out on the water, they charge about twice as much for the operation.

Another place that barriers have come into play is to protect areas that have been treated in one way or another. For example, in chemical treatment a barrier can be installed to keep the weeds from the main part of the lake from reinfesting the test embayment. In one such

treatment in Canada residents cooperated to a certain extent, although recently they decided to remove the gate because it was interfering with their boating.

Despite all efforts at isolation and keeping the populations from drifting downstream, there have been small populations established in all lakes. These populations don't really warrant the use of a large piece of equipment to remove them; instead we used something smaller in the form of our own design of an underwater vacuum cleaner. It's very costly to operate since it incorporates divers; in fact, it incorporates a 6-man crew. It's effective in a small area and it's very positive. The suction created by the pump circulating water through a venturi system deposits any material the diver collects from the lake bottom into the catchment basket, and the basket can be raised periodically and the contents loaded out and transported to shore. Divers usually work in pairs between transact lines on the bottom; otherwise they're completely lost. This is not a method you'd want to use on anything more than about half an acre of watermilfoil and that's what we've tried to restrict it to. Again, it is a preventive measure and we feel that if we can spend a few thousand dollars in getting rid of these half-acre plots, it may save us spending far more than that in the future.

Chemical Control of Eurasian Watermilfoil
in British Columbia, Canada
by
Dwight D. Baillie

Basically, the chemical program began with our Branch in 1974 with some very small applications of diquat and paraquat in the Vernon arm of Okanagan Lake. These test plots were inconclusive, but they did indicate that some control could be achieved using these herbicides, and that possibly further studies should be made of them. In 1975 we established a larger test area. This area had a very dense infestation of Eurasian watermilfoil and was a good test site because it was relatively closed having a reduced water movement through the area. We used a one-to-one mixture of diquat and paraquat. This was mixed in a tank truck and pumped out onto a boat. This experiment did prove successful in that it eliminated the weed problem in the boat basin, but only for a very short period of time. The nuisance was starting to grow back within 2 months, and this sort of limited control wasn't really what we were looking for.

We started investigating some of the other areas in North America where Eurasian watermilfoil had been a problem and some of the possible means to control it in the way of chemicals. We came up with 2,4-D and, in particular, a formulation called Aquaclean 20, which is a granular formulation of 2,4-D. In March of 1976 laboratory experiments were carried out with this granular formulation in two large sea-packs, or acrylic cylinders.

Watermilfoil populations were established in the cylinders, allowed to mature, and then one of the cylinders was treated with a minimum rate of 20 lb/acre of 2,4-D, with the result of total kill of the watermilfoil in that cylinder and no regrowth for a year and a half, which is as far as we monitored it. It did offer the hope of good control and a lasting control with kill, not only of the stem, but also of the root material. In 1976, following the sea-pack cylinder experiments,

two small areas of the north arm of Okanagan Lake were picked as treatment sites to further test Aquaclean 20. It appeared to be relatively successful, and the effects of this treatment could also be seen the following year. That, again, offered us some hope. One of the treatment sites was retreated in 1977 and in 1978. The 1976 information that we gathered prompted us to experiment further with 2,4-D to get more data on persistence, drift, and effectiveness of the chemical.

One of the sites that was involved in the 1977 treatments was a man-made canal called West Side Keys. The idea was to build this canal off the lake so that everyone could moor their boats in their backyard, and they'd have this very nice, pretty area in the back. The unfortunate problem was that they weren't counting on watermilfoil to arrive. In 1977 the canal area was treated at varying rates of 10 and 20 lb/acre. The main canal was treated with 30 lb/acre. The 1978 photos indicated extremely good control in the canal, and, in fact, shortly after the treatment (within 7 weeks) investigators were hard pressed to find a watermilfoil plant in the canal that they could take for samples.

There were actually several things attempted in 1977 in different areas of Okanagan Lake. In Oswedo Creek two areas were mechanically treated, both harvested and rotovated, and then treated, one part of the area having a herbicide treatment only. Mean stem density was calculated, a reduction noted, and on the far right side, a mean percent reduction from pretreatment determined. As a result, the West Side Key situation worked out very well with 100 percent reduction. The other areas fluctuated with varying degrees of success, sometimes based on density of the plants where we were dealing with high densities and using minimum rates, and some cases using minimum rates and deep water.

In both pretreatment samples and posttreatment samples, a decrease in species diversity was never evident. If anything, we actually obtained an increase in diversity. This is something we were seeking. Whereas machines would go through an area and remove every plant, the 2,4-D offered some hope of being able to go into an

area and remove the watermilfoil and not affect the native species.

In most cases, the maximum surface concentrations recorded were generally below the World Health Organization's drinking water standards. Persistence in most of the areas recorded was at 10 or 15 days, rather short-lived. However, in the West Side Key situation where we obtained a 100 percent kill, the water residues remained for 59 days. This was a rather expensive proposition as we had arranged for alternate water supplies for one local who had an orchard intake out of the Keys and the people who were supplying the water started charging us after 10 days, so it became rather expensive.

The results obtained from drift were also below World Health Organization standards. The maximum drift distance of the 2,4-D residue level in Skaha Lake was 140 m. These data, gathered in 1977, were used to formulate plans and programs for 1978.

The conclusions drawn from the 1977 data are as follows. The 2,4-D could be used as an effective control agent with a minimum drift situation. Water supplies could be facilitated for a maximum drift of 140 m. This would entail approximately 400 m for a drift area and a buffer zone. Very little effect resulted on nontarget species and the residue did not persist for a long period of time in the water. The water residue levels were generally below the World Health Organization standards. All these factors made this a very attractive proposition, one which, if used in combination with mechanical means, could offer a very good possibility of control.

One of the pieces of equipment used to distribute the chemical was a backpack spreader, originally used for the small sites in 1976 but still being used in 1978 to spot control areas. Another unit planned for 1977 was a large blower system. The unfortunate thing was that it tended to take the pellets and grind them into dust.

A fertilizer spreader that ran off an electric starting motor gave us a 20-ft swath, quite effective and easy enough to control hooked into the outboard engine for power.

In 1978 we were again, based on the 1977 data, hoping to go ahead with a control program and therefore prepared a unit that could cover up

to 70 acres an hour. It was the same basic idea, spin spreader, fertilizer spreader on the back, shroud over the rear engines to protect them, and a good payload on the boat. The material was stacked along the edges of the boat. A diesel engine in the center ran the actual spin spreader. The units we used were quite capable of handling up to 2000 lb of material plus crew.

One problem encountered was marking the plots. We were dealing with very large plots in Okanagan Lake and Skaha Lake and the lake systems in the Okanagan. Part of our problem is outlining the area that we want to treat and outlining the swath widths so that we can apply the treatment in the right area without too much overlap. We started out with small markers that did not work very well. Presently we are working with markers set out on the Kolona foreshore which was slated for treatment in the summer of 1978. About 13 acres of the proposed 60 acres was treated.

To maintain public safety, as on Skaha beach, we erected snow fencing. We also used warning signs posted along the beach access areas to inform the public that a herbicide treatment had taken place and that water use should be avoided if possible. We were critized for the first sign (1977) because we had not used an international sign. This was probably a legitimate criticism since we are a bilingual country. Therefore, we tried to accommodate that with the 1978 sign.

We're now working on a radar tracking system which our crews in Vernon have. The system is from Motorola; we also have a system from Agnap (United States) that we're going to be experimenting with to see how well we can use a radar system for tracking.

Some of the antichemical treatment supporters in Canada have caused us to change our programming to some extent. In 1977 our Government trucks carried the material and we drove right up to the treatment site, loaded the material into our boats, and did the applications. In 1978, however, we had to do things a little differently. We prearranged for a private motel to allow us to use their launching ramp so that no blockade could be set up to stop us from getting the material into the

lake. We hired a rental truck that had no Government stickers and drove that in. It got to be rather interesting at times. This protest aspect of the program was stronger this year than we have had before. Of course, we were planning a larger program of control. Even so, I would point out that there were only about 30 people who showed up to protest. They were, however, well organized in civil disobedience with canoes and the whole bit. Their idea was to actually go out and stop the applicator boats, to drive in front of them, and to go into the treatment area. This, of course, is what we are trying to avoid--applying 2,4-D or any chemical to people whether they are in the treatment area or not.

We did have an order in council that said this whole treatment area was off limits to the public. There is also a pesticide control act in British Columbia that says it's an offense to impede any permit from being carried out. However, that didn't seem to faze too many of the protesters. What actually happened here was that, whereas we were planning to do 60 acres, they managed to slow us down that day until an injunction could be brought against the program. The injunction was taken to court and heard and we were allowed to continue, but by that time it was the end of June and we were just about into the July 1st weekend, and the answer was "no go" on treatment for a beach area.

We basically have only preliminary results from the 1978 program. The results have not all been tabulated yet, which will probably take awhile. We're still waiting for some of last year's reports. Possibly, the most interesting situation and probably the one that's going to be the hardest for us to deal with for next year's program or any program in the future, is trying to interpret drift data that we have received this year. For instance, on the Kelowna site we obtained 1400 m of drift. It was in very small concentrations, 0.005 ppm, but still 1400 m of drift. On another site, Summerland on the Okanagan Lake, we obtained 2500 m of drift at concentration levels of 0.002. However, we have a policy at the moment for maintaining no-contact situations.

A lot of the people in the Okanagan Valley have irrigation or domestic intakes that are directly taken from the lake. With a 400-m bumper zone we could probably handle alternate water supplies for these people, but with a 2500-m bumper zone or more it becomes extremely difficult. These are the things that are going to have to be worked out this year. The reason for the drift being what it was at those two sites in 1978 and not in 1977 will have to be evaluated and some means of controlling the drift or stopping it altogether will have to be formulated. Even if it happens that 2,4-D may not be used in the open-lake situation of the Okanagan, it's possible that 2,4-D may still be, depending on water use, effective in contained bodies, like ponds, where the weed problem may be spreading.

CORPS ELEMENT RESPONSIBILITIES AND JURISDICTION IN AQUATIC PLANT MANAGEMENT

by

H. Roger Hamilton

Essentially, the Corps of Engineers has two programs in aquatic plant control. One program, which you may or may not be familiar with, is our operational and management budget. It deals strictly with Corps of Engineers water resource development projects, our lakes, our navigation waters, and waters which are authorized by Congress as Corps of Engineers projects. We fund the operation and the control mechanism, whatever it may be, for control of aquatic vegetation on the waters, at 100 percent Federal cost. This control is in the operational maintenance budget; it's very minimal and it's tied back to an 1899 law. The control is limited to certain parts of the country, and really the only people who get involved are in Jacksonville and New Orleans. I point that out because it's part of the confusion that I met 3 years ago when we were handed the program. I couldn't figure out what we did with one program as opposed to another program. That's the part that deals with Corps projects only. I just pass that on as a bit of information. I think, generally speaking, not many people would be too interested in that unless they happen to be involved in an area where a Corps project is located and where there are aquatic vegetation problems.

The program that we call the Aquatic Plant Control Program is funded in our construction general budget as a line item. It includes the three phases: planning, control operations, and research. It is authorized by Section 302 of the Rivers and Harbors Act approved on the 27th of October 1965. Section 302 of the 1965 Rivers and Harbors Act reads as follows:

> There is hereby authorized a comprehensive program to provide for control and progressive eradication of waterhyacinth, alligatorweed, Eurasian watermilfoil, and other obnoxious aquatic plant growths from the navigable waters, tributaries, streams, connecting channels, and other allied waters of the United States, in combined interest of navigation, flood control, drainage, agriculture, fish and wildlife conservation,

> public health, and related purposes including continued research for development of the most effective and economic control measures to be administered by the Chief of Engineers under the direction of the Secretary of the Army, in co-operation with other Federal and State Agencies. The local interests shall agree to hold and save the United States free from claims which may occur from control operations and to participate to the extent of 30 percentum of the cost of such operations. Cost for research and planning undertaken pursuant to the authorities of this section will be borne fully by the Federal Government.

This provides the 70/30 cost-sharing program for operations. Everything else is 100 percent Federal funding. Subsection B of that piece of legislation reads as follows:

> There are authorized to be appropriated such amounts not in excess of $5 million annually, as may be necessary to carry out the provisions of this section. Any other funds employed for control operations shall be allocated by the Chief of Engineers on a priority basis, based upon the urgency and need of each area and the availability of local funds.

That is the legislation under which we operate the Aquatic Plant Control Program.

We interface with other agencies as required by law. However, even if the law didn't require it, we would probably communicate anyway since we are in a posture of trying to communicate with other people of like interest as much as possible. We feel that we have a lot to offer in the development and maintenance of high standards in the Nation. We want to share that with other people who can take that technology and use it in their own operations. We feel also that we can learn a lot from other people, and we do.

We learn through our planning process, operation process, master planning of projects, and water resource development throughout water basins. We continually try to search the minds of other people of like interest and people who will be impacted by anything we do in there. We try to use any technology, any ideas that they have, and we get some good ones, too.

Initiation of new projects normally would begin with a reconnaissance report. A reconnaissance report normally is limited to readily available information and data. It's just like it says, a reconnaissance,

a rather early and maybe superficial identification of the problem and whether or not it's work pursuing, and if we have the feasibility to become involved. Preparation of a reconnaissance report is authorized by the Office, Chief of Engineers, which grants a specific work allowance for that purpose. Normally, we think in terms of less than $3 million, considerably less, when we're talking about a total program that is authorized not to exceed $5 million. Therefore, we're talking about rather small sums of money in relationship to everything we do here.

Concerning the authorization part of our legislative $5 million ceiling, 3 years ago, when I became involved in the program, we were averaging about $1.4 million or $1.9 million per year. This covered the whole program--planning, operations, and research. Today, however, through the cooperative efforts with the states, a few new planning problems have come to light, such as the watermilfoil problem in the State of Washington, a watermilfoil problem in Oklahoma, and the spread of hydrilla in Texas and other states. These planning problems, coupled with increased operation participation with the states and our increase in the research arena to reach our objective of providing new tools as quickly as possible to turn over for the operations people's use, not only in the Corps but everywhere, have caused a small increase in our budget. We are now getting to the point where we are starting to knock on the door of the $5 million ceiling. We're hoping that we have a high beginning where we develop the technology, conduct the research, transfer the findings out, and hopefully, phase out of the picture and put these tools to work. This is a theoretical plan that we hope works.

A problem that we used to think was limited to the States of Florida and Louisiana we're now finding all over the United States and into Canada (of course, we have no responsiblity there). We have certain species that have very wide ranges and are becoming a problem. Due to the recognition of this program and the desire to control the problem of our counterparts in other Federal and State Agencies, we have been getting increases in funding levels. It may get to the point that we have to see whether we can get a relaxation of the ceiling, or a higher ceiling, or a removal of the ceiling, or whatever it takes, at

least on a temporary basis to get this problem under control. These same problems hold true for our capability, which, in some cases, we find that we are able to get money easier than we are manpower. As I said, the reconnaissance report is the first step in identification and in the start of an Aquatic Plant Control Program in the state. When we have preliminary approval, we are required under the provisions of the National Environmental Policy Act to prepare an Environmental Impact Assessment; if the findings of that assessment are such that an Environmental Impact Statement should be done, we have to go through that process. Through this entire process we solicit and welcome the participation of others in this field, or in related fields. We welcome the participation of anybody that feels that they have a contribution to make, or an interest. Then, as an internal procedure, we prepare what we call a "State Design Memorandum" which outlines the procedures, more clearly identifies the problem and the locations of the problem, and identifies alternative ways to control the problem. This memorandum goes into a greater level of detail on how we are going to handle the problem. We also use the memorandum as a funding document to back up our request for funds to justify what we're doing. We can also include the State Design Memorandum as part of the Environmental Impact Statement and combine those documents. Sometimes this increases the rate of the procedure and we have a faster turnaround; in some cases it may slow it down.

Some of the criteria that go into recommending a project for inclusion in this program are as follows:

a. The problem and the practical measures of control are such that there is a clear and definite Federal interest under the purview of the special authority. In other words, we have to have an involvement, the authority to do it.

b. The proposed work would result in an independent and feasible project.

c. Economic analysis demonstrates that a real and satisfactory control of an aquatic reinfestation can be accomplished. We would like to go with the winners and drop the losers if we can. If we see we can't do it, there's no sense becoming involved.

d. Separable elements of a project, as well as the total project, are economically justified. We can't go out and spend the taxpayer's money unwisely, and we're not going to. We also have to balance this off with environmental considerations and other factors that may enter into the case.

e. Local interests are legally and financially able and willing to meet fully the requirements of the local cooperation. This means the 70/30 funding requirement.

During the course of working with this particular program over the last couple of years, we have developed some priorities. Since we do have a very limited funding available and quite a lot of work to do, we have to choose our projects rather wisely if we're going to spend the money wisely and obtain the maximum results from our investment. Our established primary priority is technology transfer. A variety of forms of technology transfer are available and are being used, including brochures, public meetings, interface with the public on a one-to-one basis, films, report writing on a technical level for other scientists, and one that I think needs a lot of attention, report writing for transfer from the scientist to the operations men who may not have that Ph. D., but who need to understand what the scientist is saying so he can go out and apply that chemical, introduce that biological agent, run that mechanical harvester, or whatever it is the scientist has proven will work. You can't hand a man the tool without the directions on how to use it, and he has to be able to comprehend those directions or you've got a missing link in your chain. A meeting such as this is a very noteworthy and a very good technology transfer procedure. We all learn from each other, not only in the formal sessions, but after hours as well.

That's our priority effort; that's the number one thing that we want to do--put these tools in the hands of those who can use them, and make sure that they understand how to use them.

Our second priority is research, and we've assigned two subpriorities to that: short term, being the most critical item, and long term; there are some answers we just can't get right away, we recognize that.

Our third priority is the cost-sharing program, the 70/30 requirement. It's third behind research and behind technology transfer because

we're still in the front end of that curve; we're still developing our knowledge and we're still learning. As we learn, and pass that on, these priorities may swap around.

Our fourth priority is planning, and that includes reconnaissance reports, Environmental Impact Statements, State Design Memorandums, etc. The reason this is fourth is the lack of funds. We're doing better in the funding program, but we're not as wealthy as we would like to be, so we felt an obligation to continue operations and to continue to develop our tools and put them out to the field before entering into new programs.

There are some exceptions where we have new programs that are warranted, where we have switched this around on an individual basis and started a planning procedure due to a critical need and the urgency to control a problem before it got out of hand. The State of Washington is such an example. Eurasian watermilfoil has recently been discovered. We think by rapid procedures and quickly getting the planning effort out of the way and behind us and getting into a posture of control cooperation with the State and others, we can take care of this problem before it reaches proportions that we would not be able to handle. We compare this with the State of Florida where waterhyacinth, hydrilla, and a number of other species are so proliferous that we just are not able to get on top of it in a lot of areas. It has overwhelmed us. The reason for swapping priorities on an individual basis is to try to prevent the situation from occurring again if we possibly can. We've done the same thing down in Robert S. Kerr Lake in Oklahoma where we discovered watermilfoil. We quickly got a planning effort underway, completed it, and began an operations mode. Hopefully, we can contain the problem there before it exceeds our physical and financial capabilities.

EXPECTATIONS FROM THE RESEARCH PROGRAM, MANAGEMENT PLANS, AND IMPLEMENTATION OF MANAGEMENT PROGRAM

by

J. Lewis Decell

I would like to say that the real purpose of this meeting is to find out just what the expectations should be and where we should go from this meeting. The theme of our meeting was to look at the state of the art, what opportunities and capabilities we have to use that technology, what we can expect from it, and where do we go from here. We thought it would be appropriate, even in a general sense, to just touch on some of these things as we see them now, so the remarks I am going to make will be very general.

Everyone involved in the operations phases of aquatic plant control has the right to ask the question, "What can we expect from the research program that will aid us in solving our problem?" More correctly, I think they have a right to expect and receive both an answer and some results. More and more each year as they realize the potential for a problem, the field offices are asking us this question, and I'm going to be the first to acknowledge that often we do not have a satisfactory answer and almost never do we have an immediate solution. However, I believe that we've all learned a great deal about how to go about finding a solution, and we've learned that there are probably truly no immediate solutions. I doubt that anyone here will be able to leave this meeting after these 3 days and return to their District with a solution to their aquatic plant problem. To my knowledge, Seattle is the first District to recognize the long-range value of prevention as a method of management of these aquatic plants by making an open commitment in both time and money to test that concept on an operation scale. I think this is significant because our job in the next 3 years in working with Seattle (or 4 years if it takes that long) is to sell that concept as a routine management practice to the Corps of Engineers. They do a lot of more difficult things routinely, and this concept

should be a part of routine management.

It's not a coincidence that this meeting is being held in Seattle this year. It's significant of the fact that 2 years ago the District recognized the potential of the problem in the State of Washington. Our effort was to schedule a meeting to expose all of you to their problem and them to all of you, so that there would be a technology exchange right here in this meeting.

The keynote address from Mr. John Spencer emphasized this early recognition and the need for a political basis for taking action. There are Federal criteria that require a balance of economic, political, and environmental considerations. We've been given a perspective of the Corps' aquatic plant control in relation to its overall mission. We've been enlightened about the system used to identify our research needs and how it works. We've heard about technology transfer and we've been given a sweeping view of the state of the art in all of the areas that we term control measures.

During the first part of the session we heard about our responsibilities and jurisdictions. Later in these meetings we hope to find out just what we're going to do to advance this state of the art while at the same time getting on the road to solving some of these problems in the District.

Just what may we expect from this research program? Well, first I think we can expect to see a more intensified effort to emphasize some of the short-term research that is readily identifiable as being problem related. There are several areas of research that can produce a usable result in a more timely manner for these operations management personnel. Two examples are the testing of chemical additives such as drift control and wetting agents that were identified by the Jacksonville District some years ago. We've run into a pacing problem that's not within our own agency, but the example is one of technology that is not being used. Otherwise we would be using those agents on a routine basis to effectively increase our efficiency at applying chemicals.

Second, I think we can identify fairly cost-effective mechanical systems that can be used in specific identifiable areas. I think we're going to see some more emphasis in that area. The only mission problem in the Corps' aquatic plant control area that survived the cut below 600 points was a mechanical control problem. I think that's significant. What it says is, it's the only one the Districts could all get together on and agree to vote for. Now, I think there are others they can agree to vote for, and, I think they now will have a better perspective of how their vote is used. I think it's significant that mechanical control can now be applied competitively with some of the other methods.

In the area of more long-term research, we intend to initiate some very needed basic studies that have not been initiated previously that should lead us to the ability to predict the potential for aquatic plant growth in specific environmental conditions. Although, admittedly, we've been more operationally oriented in the last year or two, we must and will continue to emphasize this basic research; as mentioned earlier, research was the number two priority, short term and long term, in that order, and that's what we're going to focus on this year, and next year, and probably the year after also.

The basic research area is an area that truly initiates the technology transfer process, and it is very essential to our successful control. We've found that some of our past research efforts have produced nonuseful results. In many cases this was the result of an inability to clearly identify our objectives to the researchers so that they could focus on an operationally oriented objective. In a very few cases, very few, we just did a bad job. Now that's not a criticism, I think that's part of the overall effort of operating with limited resources and given the charge that we've been given.

What can we expect from the management plans we've talked about per se? Well, very realistically, in the future about all you can expect is that there will be more of them in more Districts. I say this because the plan itself offers no solutions to your immediate problems. These plans are, at best, just what they are intended to be,

a yardstick for measuring progress, a road map, if you will. When you travel you use a road map, a direction-oriented device that we study in advance of our departure, used to periodically check our progress, and then study after we get there to assess our degree of progress in many different ways. That's what these management plans are, and they should be used as a management tool. To date, we've written two strawman plans from which actual operational management plans have been written. The one for the Tulsa District is generally being followed in their operational plans and has even been revised at one point; the other one was a management plan written for the State of South Carolina that was funded by their legislature. We're hoping to get some feedback from those two. Another is being formulated, and still another is in the planning stages. If these plans are not implemented, then they are simply, essentially, accomplishing nothing by their presence. In the future you are going to see more plans in various forms. This is the thrust of what we're going to emphasize in research and what the management plans are going to give us, or not give us.

What about implementation? Well, these plans I think should identify not only the timing and techniques, but also the initial and future needs. Identified and weighed against our present capabilities, this should define immediate resource shortfalls.

Once the planning stage is accomplished, to the highest degree realistically possible, our follow-through is essential. In the future we'll probably see more agencies actively engaging in aquatic plant control and following a well-thought out rational management plan that takes advantage of whatever the technology is at that time.

We talked about writing some engineering manuals. The manual is the instruction that goes with the tool. It's also a road map like the overall management plan, but these manuals are going to be written while we're in the process of learning to do this job more efficiently, not before we start on the job.

The valuable experience of implementation will be truly usable because we'll have a road map against which to measure our progress; if our progress is unacceptable, then we need to know this as soon

as possible, and we need to know why. You're going to see more Districts writing these plans and having more input into these manuals with less help from research people as time goes on.

We've now got two manuals in draft form. One is being held up for a reason that is probably not readily apparent, but is a very frustrating one. The reason the manual has been in final draft form for about a year, and hasn't been released to the field as an example to get some feedback, has to do with the use of insects for control of aquatic plants. At present we have an interagency agreement with the U. S. Department of Agriculture (USDA), and have for years, so that we can buy the capability and expertise they have in this area, quarantine facilities, etc. Agasicles is an example of a successful biological control for alligatorweed that was released in a brush-fire-type operation, putting out the brush fires. It gained control of the alligatorweed and until last year, when we initiated a survey, there had been no report of any increase in alligatorweed in the Southeastern United States for 3 years. However, like all biological agents, environmental conditions favor the survival of the weed, and eventually we're going to have to restock these organisms. For Agasicles, that was last year because alligatorweed is on the increase in a lot of areas of Louisiana and other southeastern states. The problem is that the insect is not an off-the-shelf type item that can be obtained anywhere.

We've got a manual ready to go that says you can calculate the number of Agasicles needed to control the problem. Realistically, we should be putting them out whether needed or not on a routine basis, because when the problem starts to peak we know it, and we can put the insects out to keep the peak down. However, there's no place to go to obtain the insect. Somehow, in the process over the past 10 years we've all failed, and some people before us, to recognize that there has to be some facility for maintaining, in some form, a population from which we can draw to restock. We're trying to prevent this failure from recurring. There's a real problem between the Corps and the USDA on who should have this facility, what it should look like, who should maintain it, who should pay for it, etc.

In any case, that's the reason the manual is still in draft form, and we don't want the same thing to happen to the manual on chemical use and the manual on mechanical use. The problem of supply is not the same for the other two types of control. There are chemical companies that will sell you all the chemicals needed. We've got the on-shelf supply there, but that is the kind of thing that's happening to the manuals right now.

In summary, I'd like to list what I think the future holds in terms of aquatic plant control:

a. More management plans will be written by more Districts with less and less help from the research teams. These plans will be routinely followed and will be a much more efficient means of control and true maintenance and prevention of aquatic plant problems.

b. Implementation of the control methods will become easier and more effective as a result of recent technology. There will be more feedback to the research team from the operations personnel so that researchers can focus better on the problems.

c. There will be more timely application of technologies to immediate problems without the erroneous expectation of an immediate cure.

In an overall sense, the Corps' future role in aquatic plant control will be a more effective one in which all that are tasked with certain responsibilities know how to solve their problems through good management practices and that the true nature of the problem is recognized.

QUESTION AND ANSWER SESSION

LTC Phillip E. Custer (Panama Canal Company): "I'm not really familiar with the aquatic plant problems of various Districts in the United States, but we have one problem down in Panama that I think other people may have a similar problem with and maybe they could give us some help.

We feel that hydrilla and hyacinth are occupying a niche in our lakes that, when we eradicate them (and we have a great deal of faith that we will in the future eradicate them), hyacinth particularly, that this niche will be taken up by Pistia (water lettuce). You've told me that there's no ongoing research within your organization to find out how to get rid of Pistia as a target species. I know it does exist in the United States, and I think this is more than a question, it's a comment. Maybe some of the Districts in the southeastern part of the United States ought to be looking at this and similar problems, that when they do eradicate one target species, another comes along to take the place of it. We particularly are looking for ways and means to deal with Pistia because we think that in the next 6 to 8 years, we're going to have that problem. Right now the state of the art concerning that particular plant is only the use of a very toxic poison, which you probably can't even use in the United States, and we kind of shudder when we have to use it in the Zone."

Lewis Decell (WES): "You're exactly right, Phil, and that's not embarrassing. We are not studying Pistia simply because of what we've discussed before. We've got just so much money and just so much emphasis and we've established a priority of our problems. Some Districts have had problems with Pistia and sometimes we measure the effectiveness of our control of waterhyacinths by measuring the acreage of Pistia that comes in right behind it."

E. E. Addor (WES): "It happens that on some of my sites in Louisiana I'm looking at right now, I have observed the succession of Pistia following loss of waterhyacinths, and we have initiated a preliminary investigation into some of the problems Pistia may propose."

James T. McGehee (Jacksonville District): I think COL Custer is very rightfully thinking that he is going to have some difficulties of replacement. It's a very real problem we have in the Jacksonville District, not only Pistia (water lettuce), but we also have duckweed and other plants that will move in and take up this niche. On the floating level, we have found that in some of the areas as we either mechanically or chemically treat hydrilla, we're having Cabomba and other plants come in, and we have asked the Chief's Office for approval to treat these things on a limited basis so that we can keep open the areas we have intended to have open. The material I believe you use as Pistia control is paraquat and I don't think we will be using it up here; but diquat is quite effective. We do have a Pistia control program in conjunction with our waterhyacinth control program that seems to be working quite well."

H. Roger Hamilton (OCE): "When we started this program about 3 years ago, we identified two major problems of concern that we needed some information on; we still don't have the information, but the two areas of concern are natural succession and plant physiology. Natural succession is when you kill one plant, another one is going to come in and take its place. What do you do with that? What do you do with the third one that takes its place when the second one is gone? What can you predict? What kind of treatment scheme or management scheme can you lay out on an integrated basis that's going to knock all these characters out as they fall in like dominoes?

The second area is plant physiology. Can we identify the weak point of the plant and attack that weak point? These are both long-range type research efforts that are about a third priority, behind short-range research and technology transfer. Lewis is right, they're not doing a whole lot on that, primarily because we have not been giving them enough money to do it. They are, however, areas of concern and we share your concern, Phil, not only on Pistia but other species as well."

Katherine C. Ewel (University of Florida): "I think Mr. Hamilton raised a very, very good point, and that is that the niche will still exist regardless of whether you can do anything with Pistia. I would like to see a little bit more attention, not so much toward aquatic plant management, as ecosystem management, and looking at ways in which you can change what's happening in the ecosystem to bring about that niche."

Mark Follett (Seattle District): "I think Kathy pretty much hit on what I was going to talk about, and that was, it seems to me that there needs to be a little more attention paid to what is the root cause of our aquatic plant problems. METRO, the local agency here in Seattle, in a questionnaire that they sent out to the local people, got answers back indicating that people felt that one of their major water quality problems in the Seattle area was aquatic plants. This has been a fairly recent development in the Seattle area mainly resulting from the increasing urbanization with urban runoff and septic tank effluent. We're enriching these lakes and encouraging the growth of aquatic plants, and that's the root cause of the whole thing. Perhaps the Waterways Experiment Station of the Corps of Engineers may not be able to address that problem, but certainly there are other agencies, among the EPA, who can address the question; there also needs to be a little cooperation between EPA and some of the local agencies such as METRO."

Dr. Leonce Bonnefil (Puerto Rico Department of National Resources): "In Puerto Rico, we are considering weed control, not the control of one weed, but as a complex of weeds, the reason being, if we eradicate one and don't try to eradicate the others, we don't have the problem solved. One example of this is paragrass. Paragrass makes it impossible sometimes to control waterhyacinth. Do any of you attending this conference have any problem with this tremendous pest?"

Dr. Kerry K. Steward (USDA): Paragrass is also a problem in Florida. We found glyphosate to be a very effective control of paragrass, around 2 pounds per acre or something like that."

J. C. Joyce (Jacksonville District): In response to the comment about the water quality considerations, I would like to point out that

in Florida and also in Louisiana, we had problems with waterhyacinth before we had your, let's say, people problem--pollution problem. The point I'm trying to make is a lot of these exotic plants have the ability to come in just with the natural level of nutrients and create a tremendous problem. I agree with you that we may be enhancing some of these problems, but let's not forget that some of these plants have the ability to be a problem with a pristine type of environment. One of the questions COL Adams wanted me to ask is why isn't USDA involved more in total aquatic plant control research?"

Dr. Kerry K. Steward (USDA): "Time and money--we have neither."

J. L. Decell (WES): "I might make a remark about COL Adams' question, because I've been asking the same question from the research end of the Corps for 3 or 4 years. I want to preface my remark with the fact that Dr. Steward, Dean Davis (the Regional Director of the Scientific and Education Administration (SEA) in that area), and Bill Larson (SEA assistant), have met with me many, many times on this same issue, and they feel the same way we do. They have a situation where they can't get the money to maintain the basic capability that we're trying to use with our Corps money; it is a problem and a very valid question. I assure you that all the way up to the national program staff in USDA there is an attempt being made to solve this problem, and Dr. Larson and Dean Davis have worked very closely with us. So, I don't know what the answer is going to be, but they are cognizant of it, COL Adams, and we're trying to do the best we can to solve it."

J. C. Joyce (Jacksonville District): "I know its probably changed 10 times and will probably change 10 times after you get back, but could you briefly describe the structure of your new research and development organization once you get reorganized?"

J. L. Decell (WES): "At present the Waterways Experiment Station, in particular the Aquatic Plant Control Research Program (APCRP), is undergoing a reorganization. The Waterways Experiment Station is made up of several laboratories that devote themselves to certain missions within the Corps for research. Prior to several months ago, one laboratory was known as the Mobility and Environmental Systems

Laboratory (MESL) of which Mr. W. G. Shockley was the Laboratory Chief. There was also an Environmental Effects Laboratory of which Dr. John Harrison was the Chief. The Environmental Effects Laboratory and the Environmental Systems Division, which my Branch was in, of the MESL were combined--so half of one lab combined with the Environmental Effects Laboratory to form a laboratory that's now known as the Environmental Laboratory with Dr. Harrison as Chief. This Laboratory is in the process of forming two Divisions, and they're presently in the throes of wrestling with the formulating of mission and function statements for each of those organizations.

Now, what about the APCRP which has been the program in my Branch and the people in my Branch that have been doing the work? What happens to them? At the present time, I'm serving a dual assignment as Branch Chief (until the new Divisions are formed) and also serving as Program Manager reporting directly to Dr. Harrison. After the new Divisions are formed, which should be in November or December, I will make recommendations as to the assignments of APCRP work. For instance, biological and chemical control may well be assigned to different Divisions; however, I don't know at this time which Division should do which work. I'm confident that in most cases the work package assigned to each Division will include people in my Branch who, in the past, were associated with the work for continuity. My point of contact on the work will be the Division Chief and there will be Group Leaders below them comprised of research teams. I've heard concern about the new system being as efficient as the old one. I share some of these concerns, but I can tell you that we're all working very hard to make sure that it doesn't affect the rate of progress of the program or any communications we have with the rest of the Government Agencies and the District."

W. N. Rushing (WES): "I think maybe it would enhance the answer to that question to describe the Program Manager concept just briefly, if that's possible."

J. L. Decell (WES): "The Program Manager concept is one in which the technical divisions do the technical work. There are Program Managers, two or three, in the Laboratory who report directly to the

Laboratory Chief. They say where the work will be done and who will do it. Their job is to respond to OCE on the program objectives and tell the Divisions what the objective is, and what the time frame is for getting the work done and how much money is available. How you get it done and how you mobilize the research teams to do it is the responsibility of the Division Chief; the Program Manager doesn't tell them how to do it.

The Program Managers (and these are the words of the Laboratory Chief) are viewed (almost) as outside sponsors. The Program Manager assigns work to a certain Division because they've got the capabilities, the mission, and the technical expertise to do it. From an optimistic viewpoint, and I am optimistic about this new organization at WES, it is going to make available a lot of new technical capabilities that were not heretofore readily available; I think that's a plus, and managed correctly, we're going to have some bright people in specific areas of endeavor that are going to help us solve some problems.

J. C. Joyce (Jacksonville District): "What's bothering me is that you said we got a lot smarter. Well, I think in the last 3 years we've gotten a lot wiser, I don't know about smarter. At the front end of this whole research program we spent a lot of dollars quite frankly educating researchers, and I just hate to see us start that cycle again with another batch of people coming in. But, if we have the continuity that you've expressed, then maybe we won't have that problem. I just hate to see another whole group come in and we spend the money to educate again. That's my concern."

J. L. Decell (WES): "I assured you of that from the very first, and all I can say is that I'm pushing to maintain continuity, and I think we'll get it. I have had no indication in the past few weeks that that's not going to happen.

Ohren Keckemet (Pennwalt Corporation): "I think there are two types of people here, which also happens in other aquatic meetings. The minority are those who are pushing specific lines of products, this could be mechanical, chemical, or biological, because they are paid to do this by their company, or they are getting grants-in-aid, or they

are going to get the paper. Fortunately, this is a minority. Majority-wise, those here are concerned with the control of aquatic weeds at large, regardless of method. Even though I'm working for a chemical company, and I've been working for 20 years on aquatics, nationally and internationally, I'm in that second group. Let's do the best, regardless of method. Now you all know that 20 years ago, it took us about 40 to 50 pages to register a product for aquatic weed control or algae. It was primarily basic toxicology and a few performance results. Today we are going in with maybe just 1 or 2 ft of paper on performance and toxicology and the rest about 7, 8, up to 15 ft of paper is concerned with side effects. Now by talking about side effects, it could mean part on microbes, chemical on microbe, microbe on chemical, anaerobic, aerobic, wildlife, fish, changes in the physical/chemical properties of water (not only immediately after application but for 1 or 2 years later), disappearance, and so on. What concerns me about what we are talking about and spent quite a bit on is what will happen in 10 to 15 years in regards to insects, diseases, white amur, and so on. At this point everyone is concerned only about performance, does it do the job or does it not do the job. That's the easiest part. So far I haven't seen any evidence, except a little, about impacts. When we are talking about diseases, plant pathogens to control algae, we are talking about <u>Cercospora</u> just to mention one, which is the main problem as far as crops are concerned; we are doing something against USDA, EPA, and Government rules by spreading diseases. We are spending millions to control <u>Cercospora</u> on peanuts, soybeans, potatoes, or whatever. So, before we get too far, let's look a little more at possible side effects, the same as EPA neglected 20 years ago in respect to chemicals, and they woke up 20 years later and they're asking for all of these side effects.

Insects are a similar thing. After the insects clean out alligatorweed, or whatever, they start showing up somewhere else, could be crops, desirable crops.

We are talking about economics, certainly, and about emotions, and we shouldn't be concerned only with what a control method is going to do

two months from now. We should be concerned with the long-range side effects because, sooner or later, whoever is working on that will get hit with that and it will be too late. In the chemical industry, we have already learned that you can have the best short-range results, everything looks fine, but this is not looking 10 years from now. You can spend $4 million or $5 million, or even more, not spend--waste--because you will find later that whatever you did hurt something of worth."

J. L. Decell (WES): "I would like to address your comment briefly, and then there are some people I would like to have respond to give you some assurances that I think we owe you, and to some other people, an apology. I guess, just due to time, that when we talk about performance, that we don't mean to use any method that's not environmentally compatible with the aquatic ecosystem and the surrounding area. I can't stand here and tell you, maybe Dr. Freeman could if he was here, about the fact that he has to go through the same process of registering *Cercospora* as a chemical company does with the chemical registration; I can assure you that we look at the effects on the aquatic ecosystem of our control actions before we make a decision or conclusion that we have a viable control. It's got to be environmentally compatible, be it mechanical, chemical, or whatever. In direct effects, for example, in our use of the white amur, we've got an extensive modeling study being conducted by Dr. Ewel in which we've got a predictive model that we can use that tells us what happens if we use 10,000 fish of one size on a described weed problem. We're looking at a 10-year cycle in the iteration of this thing, but we haven't made a decision on the stocking rate because we must take one that gives us an acceptable level of performance and the data are input into the model that looks at the response of the ecosystem to that particular control measure. It's only after everything looks acceptable that we determine if we've got a stocking rate we can use. We're also approaching our other control methods more and more this way; I think I can say that we agree with you on your concern, and we're addressing these things in the program, although they haven't specifically been brought to light in this meeting."

Obren Keckemet (Pennwalt Corporation): "There are no rules for registration of chemicals at this stage; there are guidelines which are a few hundred, a few thousand pages long. Who is working on developing guidelines for registration of mechanical or biological methods? Again, let me point this out, I'm not prochemical and I'm not against other methods; I'm concerned with control but I would like to know if there's any information on developing guidelines for registration with these other methods."

J. L. Decell (WES): "As far as the insects go, there's a very rigorous system of approval and date of collection in quarantine that's followed to make sure that the insects are host specific to that particular target species, before permission is given to release them at any scale in the United States."

Dr. T. E. Freeman (University of Florida): "If we bring in an exotic pathogen, we have to go the same route that you do with insects. There is a biological control, the International Working Group for Biological Control, which has to approve the importation of any exotic organism brought in for potential biocontrol usage. As far as endemic species are concerned, there is a group primarily headed by the EPA to set up guidelines for the registration of pathogens used for biological controls. They have been studying the situation for 4 years. They held a meeting in Arkansas about 4 years ago to begin to formulate these guidelines. In the very beginning the guidelines were the same as the chemical guidelines with a few added ones that would have put a screeching halt to any type of research on the use of plant pathogens for biological control because we would never have been able to satisfy those guidelines. They have softened them somewhat, but they are still very rigorous, and I daresay we will have to go through the same thing you have to go through with a chemical, plus we'll have to prove that they will not affect crop plants; we'll have to prove that they will not adversely affect the aquatic environment just as you do; there's also one requirement that's called genetic drift in which we will have to prove reasonable genetic stability within the pathogen or insect, which is going to be difficult to prove, I'm sure.

We started out having to prove safety against deer, wildlife, fish, ducks, shrimp, and everything else. We're probably going to have to meet more rigorous requirements for plant pathogens than you are for chemicals when it comes right down to the final analysis. Whether or not we'll ever be able to use an exotic pathogen as a biocontrol in this country is highly doubtful.

In respect to your comments concerning *Cercospora* species, you're entirely correct, but note that there are different species of *Cercospora*. You're in the chemical industry, so I assume you know that the *Cercospora* that attacks a peanut, for example, is not the same *Cercospora* that attacks waterhyacinth; the reverse is true too, the one that attacks waterhyacinths will not attack the peanut. We have used two separate methods to test this fact. The centrifugal method works out from related plants; in other words, we take the waterhyacinth and then we start going to related plants, under the assumption that if an organism will attack another host, it is more likely to attack one that is closely related to the original one on which it occurred. We also test for economic crop species. We have tested roughly 85 other species with *Cercospora rodmanii* and have found no others that it will attack thus far. Believe me, our inoculation procedures have been tremendously more rigorous than any you would find under natural conditions."

Dr. George Templeton (University of Arkansas): "I just want to add my endorsement to what has already been said about specificity of fungi at the host genus level. I think it's generally oversold that plant pathogens are variable. Usually, this variation occurs at the variety level in the plant group. You hear about races of rust, and you hear about races of the organisms that caused the corn blight problem. These things made a very dramatic story for the newspapers; but, generally, most pathologists agree that you very rarely have plant pathogens crossing host plant genera lines, at least not in the higher pathogens that we're involved with in the biological control effort. We've had experience trying to work with EPA for a number of years on a registration of a fungus for use in rice fields, and they have required us to ensure the specificity, the stability of the organism, as best we

can. They have also required that we try to infect mammals. We've tried it on rats, rabbits, guinea pigs, chickens, turkeys, ducks, quail, crawfish, trout, catfish, and earthworms. We have not been able to infect, in any case, any animal, or even cause an allergenic reaction in any of these animals, with excessive doses of our fungus. We are proving things that we have been telling our beginning pathology students for years, that plant pathogens do not infect humans. They may is some cases cause allergenic reactions or toxicities if ingested in large quantities.

Microtoxins is another area of concern by EPA. They're concerned that in a crop like rice we will possibly have a buildup of microtoxins. Here again, we have not been able to demonstrate the present or the experimental production of microtoxins in rice grains, so we feel definitely sure of the safety of this system. Of course, we are working with an organism that is out there already anyway, so we're just augmenting it, and augmenting it in very restricted localities. I would like to mention that we are in the process of working with the Upjohn Company in making our registration application to EPA; we have been directed to Dr. Martin Rogoff, Dr. Ray Engler, and Dr. Jim Ackerman for guidance in how to make this application.

One of the other things that I failed to mention that EPA is probably going to require us to do is to show that we can control what we put out. We'll probably have to use chemicals to control it, but we'll have to prove that we can control the disease once we put it out."

Gary Hansen (Bureau of Reclamation): "I'm not a researcher, much has been said about research; I'm an operations and maintenance (O&M) man. I'd like to say a little bit about one or two of our problems that I think are quite important to mention. I admit that I'm a little biased being an O&M man. I get a little impatient; I'm also a little bit pessimistic because of the administrative and regulatory hangups that impinge on our operations as maintenance people, and I admit that it has been stated that we probably need to study more about ecological balances, but we have some problems where we can't wait for that kind

of study. That takes a few years, quite a few years, quite a bit of time. We have hydrilla now in our All American Canal System in the Imperial Valley. This is an intensive agricultural area. They raise crops 12 months out of the year down there. We've got hydrilla in our system, some 368 miles of canal are now infested with hydrilla. We do have some other aquatic plants down there, namely Eurasian watermilfoil and, of course, <u>Chlodophora</u> algae and a few other varieties that were there before hydrilla came. As far as filling niches, if we ever get rid of the hydrilla, I'm not really that concerned about refilling that niche because up until then we had Eurasian watermilfoil which didn't seem to be a problem in that system. Now we've got hydrilla. It <u>is</u> a problem and if we don't get in there and get it out, we are going to shut down that Valley. It's that serious. It's going to get in the rest of the system and then we are in real trouble. My whole point is, we have a couple of chemicals, maybe more than two, but we have at least two, that will provide quite effective control. I don't think we're ever going to eradicate it, but it will effect adequate control. The problem being, of course, that neither one of these chemicals is registered for that particular site use--an irrigation canal. That water is used for irrigation, it is used as a municipal water supply for a city of 17,000 to 18,000 people, there are a lot of people south of the border who use it for potable purposes, and it also serves as a fishery. So it serves as a fishery, irrigation water supply, and a potable water supply. We've got the chemicals to clear it out. But what are we faced with?

<u>a</u>. Neither one is registered for that specific site use.

<u>b</u>. If we have to go through and file EIS's under the NEPA or under the California State Environmental Protection Act, we are not going to control hydrilla.

We've got to get on it now--we can't wait for 1 or 2 years. We can't wait to see what ecological niche is going to fill in after we get rid of it, if we ever do. We've got to do it now, and we are not doing it. We are sitting there and it's growing and it's spreading.

We are arguing and striving and working trying to get around the administrative hangups and regulatory hangups. We're not getting very far, Gentlemen."

Tom Sawicki (Orange County Pollution Control Department, Orlando, Florida): "I have two concerns. One is the lack of any mention of restoration techniques for lakes. Some of these restoration techniques can control aquatic weeds. There is a treatment using aeration that is claimed to control aquatic weeds, in addition to using up the nutrients already in that ecosystem. Then, of course, there's drawdown, and several other such techniques that could provide good aquatic weed control. I'm concerned also about a second problem that has not been addressed in any of the presentations, and that's going upstream. We are concerned with the alternations of our ecosystem. We see a progression also in our lakes; they are continually being degraded. Even when they look pristine, things such as water control will cause a lake or a stream to degrade. We have alternations in the water usage, recreation, for example. Those patterns will cause the release of certain nutrients, and the niches are then created for the introduction of native as well as exotic species. We have, in addition, the increase in nutrients and biomass and the release of nutrients from the reservoirs and the sediment. None of these items have been addressed, and yet all of them have an effect on the growth of aquatic weeds, whether they are exotic or native species. Even in so-called pristine environments, we see these problems occurring. It seems to me we should go somewhat upstream and look at measures for controlling our ecosystem before these problems occur. I'm wondering what kind of efforts the Corps is taking along these lines?"

J. L. Decell (WES): "Lake restoration, per se, is not our charge in this program; but, I agree, we have looked at drawdown and people in the State of Florida have used drawdown, and there has been a successful drawdown in Louisiana. I can only say that we probably are not pursuing it with the intensity that we should as an equal with some of these other methods. This is because most of the Corps projects in which we have aquatic plant problems are multipurpose and we run into the normal

conflict. We've dealt with the problem before of a conflict of the water usage in the same reservoir. When you look at trading-off, not lowering the water below a certain level, that maintains the power of generation capability, the potable water supply, the recreation during a certain time of year, you find that lowering the water may affect 2 percent of the total problem. When you begin to make the trade-off, you realize it isn't worth it, on the large scale. I'll be the first to agree with you that in smaller bodies of water that may well be a very viable tool. We are keeping abreast of what's being done, but we're not devoting any funds to research on a equal basis with the other methods of control."

H. Roger Hamilton (OCE): "One of the things Tom's talking about is the control of the introduction of nutrients upstream and I have to agree that a lot of the things we're doing, harvesting weeds, or killing them with chemicals, etc., in some cases, we're just giving aspirins. If we could control the introduction of nutrients, we may be able to prevent having a problem. Now I also recognize that some of these exotics are going to grow under pristine conditions, under the normal amount of nutrients in the water; however, if we can control the introduction of nutrients, we can certainly reduce that effect, if not eliminate it entirely in certain conditions. In the APCRP I don't think we're doing anything about that. In other programs of the Corps, primarily in cooperation with EPA, we are doing some things in this field. We're working on better, more effective, and more efficient ways of water treatment systems for municipalities, and we're constructing some of these systems. It's not an aquatic plant control problem; it's not in this program. It is something that we're doing in another program which I think will give some benefits in this particular area.

I want to take one minute and address the comments of the gentleman from the Bureau of Reclamation in the Imperial Valley. I work in operations also; I share your concern. At the same time, we have to recognize that we have to at least have an environmental impact assessment. If the results of that show that we have to have an environmental impact statement, we've got to do it if it's a significant Federal action.

It's required by law, and we have to obey the law. If we see, or somebody else sees, in their wisdom, that that's not the way to do it, then the law has to be changed; but as long as the laws exist, we have to comply with them."

Gary Hansen (Bureau of Reclamation): "It's true that that's the law; however, I think sometimes we get caught in a trap where we go along with the idea that we do need an EIS or an EIA in every case, and I think sometimes we don't. I think some of these things are maintenance problems, a regular maintenance operation, and they're not something special. Yes, hydrilla is special. It's a different weed than we've faced before, but we've controlled other weeds in that canal, and sometimes I think we get in a trap where we think we have to file an EIS in every case. I think we should take the other alternatives that are open to use and get around it as much as we possibly can in these types of situations."

E. E. Addor (WES): "In response to the conversations that have just occurred here I want to make these comments simply to add these thoughts to the proceedings. I'm not offering any solutions here. Regarding the upstream problem and the ecosystem problem, we're talking about chemical additions to the lake which induce eutrophication, etc. Possibly there is an analogy here to the problem of soil erosion which has been addressed through the nonpoint source erosion problems. We might do some thinking in developing that analogy for application to our problem.

The other point that I would mention is that I have in my literature clippings someplace, somebody has suggested, and apparently succeeded, in using a negative eutrophication, I guess that's one way to call it. He added a chemical to balance the chemicals that were in the lake that were out of balance; that is, he added a kelate or something to settle out the excess phosphorus or to absorb the excess nitrogen. Our problem appears to be, in the case of a nonpristine situation, one of a chemical imbalance. We can add the extra phosphorus, nitrogen, or carbon--those three chemicals have been particularly implicated, and

that might be an approach that we could use. The Corps is not approaching that, although, as I say, the idea has been in the literature."

John H. Neil (Limnos Ltd., Canada): "It seems to me that the greatest opportunity for management, once the problem is beyond the practical possibility of containment, is utilization. The great opportunity is there and it is a topic which we haven't heard any discussion on at these meetings. The fact that such tremendous tonnages of these materials are present has always been listed as a great problem as far as the mechanics are concerned, but with improved harvesting techniques the economics of removal can be greatly improved. We can look at this as an opportunity to turn this problem into a resource. There's feed for a steer in every acre of that material out there for a period of a year. It's not a complete food; we have to look at other alternatives, but in the Florida situation there are things like Begas which can supply the energy that's missing, and there are things like coarse fish which can be used to provide any protein shortfall. This is only the beginning, because there are opportunities for fuel and fertilizer; nobody really has ever looked at the other opportunities in terms of growth hormones, vitamins, and things of that nature. I recognize the fact that the Corps' mandate doesn't include the development of these uses, but here lies a great crack which these opportunities fall through. It scares me in a way to hear some of the successes that have been achieved by the insect and pathogenic controls because I think one of these days we're going to be applying insecticides to control the insects to allow us to provide an aquaculture crop of considerable value.

I wonder whether you, Mr. Decell, agree with this philosophy, and secondly, where do you see the mechanisms to put wheels under what I feel is this great opportunity, and turn the problem into a resource?"

J. L. Decell (WES): "I agree with the basic philosophy that there could be resource to be gained from the aquatic plants that we may harvest mechanically. I'll just briefly tell you how I perceive the total system. I do not accept the philosophy that if I can sell a ton

of hydrilla for $100 that that cost is going to be returned and thus lower the cost of harvesting, and thereby one solution helps solve the other problem. I'll draw an analogy to explain why I don't believe that. If we find a productive use for these plants (and I might add that I think we should pursue that), I think you're going to find that the cost will not be returned to defray control costs because of logistics costs, and the unsolved problems in over-water transportation of the harvested material. We are going to find that people are going to farm the weed just like they successfully farm catfish. The Mississippi River is full of catfish, but the economic benefits derived from the sales offset the capital cost of investment in a catfish farm but not in the logistics costs of fishing the Mississippi River. We've got a situation where the very trait that makes the weed a problem, which is a prolific growth rate under a wide range of nutrient conditions, is going to provide the capability to farm them at the back door of the factory. I don't think we should kid ourselves that there's money flow in the system that is going to solve each other's problems."

Loren Mason (Tulsa District): "I think there can be great mileage obtained with a change in the title of our meeting. You and Roger have, I think, paved the way for a dawning of a new era, and that is cooperation between researchers and operators. Therefore, I think our title should reflect that. We should have an aquatic plant control research and operations program. I think we can gain a lot of mileage with that in there, and it recognizes both sides of the issue--research and operation.

I would also like to see more research oriented toward natural recession of aquatic plants. A specific example in the Tulsa District concerns Eurasian watermilfoil. Last year we had approximately 1600 acres of Eurasian watermilfoil in Robert S. Kerr. However, this spring when we went in with our treatment program, we could only account for approximately 800 acres. Something happened between last October and June of this year, and we don't know what. We're reasonably sure that the winter kill did not cause that much reduction and we are reasonably sure that we didn't have a herbicide drift. What we'd like to know is

are there some natural phenomena, whether it be pathogens, insects, or water quality, causing this tremendous recession in this particular plant? We don't know if this is a cycle phenomenon that we're going through or whether other Districts have had this problem. I think it deserves to be looked into from a research standpoint. Maybe we're talking about just a physiological study of the plant. Whatever it is, I think it needs to be looked into and not only for Eurasian watermilfoil, but for other aquatics."

J. L. Decell (WES): "Other Districts have had this problem. You ought to get with Joe Joyce. He took credit for the disappearance of 9000 acres of hydrilla and doesn't know how he did it."

Elwood A. Seaman (U. S. Bureau of Reclamation): "I had the privilege of attending the Second World of Ecology Congress in Israel a few weeks ago. At that congress Dr. Levender presented a paper on the program he has in the Israeli National Water System on the handling of certain species of fish and his control of aquatic plants. I took the privilege of taking another week in going over their entire water system. They pump water out of the Sea of Galilee, now called the Kinneret Lake, up several hundred metres from below sea level into the cities and irrigation areas throughout the whole country of Israel down into the Negev Desert. They supply water to Tel Aviv, Haifa, Jerusalem, Jericho, etc. I don't think too many people in the aquatic biological field, especially those in fisheries, have been paying much attention to Levender's work. He's been publishing in rather obscure journals and I'm not so sure too many of you are aware of these papers. At the present time I'm putting together a report on my observations over there and if any of you have any particular interest in them, let me know and I'll send you a copy. What he did was what we can't do in the States. He's using grass carp, black carp, silver carp, common carp, and four species of Tillapia, plus one mullet; one of them is a sea mullet as well as a sea bass, and many combinations to do various jobs in reservoirs. He's using them very effectively. He has certain species that eat the higher plants. He had a terrific plant problem when they first built the reservoirs, the reregulating reservoirs, and the

settling basins because the water temperature was about 50°F year-round, and the plants just grew wild. However, he's totally eliminated all the higher plants by this fishery program.

He pumps various species of algae plankton from the Sea of Galilee. Though they live in the Sea of Galilee and have big blooms there, when he pumps them into his reservoirs, they die off (of course, a little chlorination helps). When they die off and settle to the bottom, he has a very critical taste and odor problem in the water. Now for thousands of years the people in Israel drank well and spring water and they sure didn't like this fishy, musty odor taste in this modern system of water delivery. Levender has solved this problem completely by fishes. He has certain species that eat the plankton, fishes that eat the residue of dead plankton on the bottom of the reservoirs, and fishes that eat all the higher forms of plants; he even has one species, the black carp from China, which eats the snails, and thereby controls bilharzia in case that could ever be a problem in Israel.

So his management technique is rather significant and very sure. It's one of those things that just drives a management biologist crazy. I tried to explain to him that when I was Chief of Fisheries in a state in the United States, I couldn't do with the fishes what I wanted to do because of the many regulations within my State and the regulations of other States, Federal regulations, etc., of moving exotic fish around; of course, these are more stringent now than ever. He said "Well, go do it anyhow!"

We don't have that privilege in America, as yet, but the research work he's done is quite significant. He has a closed basin; he can pump the water out of the Sea of Galilee up above sea level and distribute it all around. The end point is the desert or a little bit going down in intermittent streams to the Mediterranean or down into the Dead Sea. He doesn't worry about where those species of fish may spread.

I just wanted to bring this to your attention. I don't think too many research people in fisheries are aware of the work that he's doing over there and I think it's quite unique.

My second comment concerns a one third acre pond in which I raise rainbow trout. An engineer in my neighborhood snuck in one dark night and put 12 goldfish in my pond. At that time I had a very bad Potamogeton pectinatus problem that was taking over the pond. I gave it some chemical treatment about 3 or 4 years ago and knocked it down. The next spring it came up better and thicker, 6 ft out from the shore, and 6 ft deep in this one third acre pond. The goldfish were still growing and doing real well in there, and I didn't pay any attention to them. The next spring the Potamogeton, as well as smartweed, came in that one third acre pond and just about wiped it out; you couldn't even swim in it. One night the plankton bloom died off, the pond cleared, and I saw that I now had 200 to 300 goldfish. When I came back from Israel, there were no aquatic plants in my pond. I was really surprised at this. I immediately checked the literature on goldfish to see how effective they were in aquatic plant harvesting, knowing very well that they were herbaceous eaters and knowing something about their habits. I made a literature search immediately, and I'm just astounded at the vacuum there is in the literature on fisheries concerning goldfish and how effective they might be in harvesting ponds. They totally wiped all the Potamogeton out of that pond. I saw them actually eating the last smartweed on the edge of the pond, coming out of the water to get it in fact, which is kind of shocking.

Maybe we ought to be looking at some things of this sort, digging into the work in Israel and their combination of fishes. Yes, there's research going on on grass carp, etc., but I think that the biological side's got a long way to go. The fishery side, one of my biases, can be very effective, and I would urge that we pay greater attention to this."

TECHNOLOGY AREA GROUP DISCUSSIONS

Instructions and Charges to Technology Area Groups

by

William N. Rushing

The technology area groups for the 13th Annual Meeting of the Aquatic Plant Control Research Program are as follows:

Chemical Control Group--Dana R. Sanders, Chairman

Biological Control Group--Russell F. Theriot, Chairman

Mechanical Control Group--Perry A. Smith, Chairman

Integrated Control Group--E. E. Addor, Chairman

The reports from these groups will be used to determine partly the Aquatic Plant Control Research Program for FY 79-FY 80. There are, of course, certain things that are already locked in, but certain areas can be changed as the result of findings of these sessions.

Each controlled technology group, taking into consideration the current state of the art, is charged with the responsibility of responding to the following questions:

a. Identify controlled technology gaps that need to be filled within the next 3 to 5 years to provide an improved operational capability.

b. Identify the research effort needed to develop the technology to fill those gaps.

c. Identify alternatives, if they exist, and approaches to conducting this needed research, including realistic time frames for completion.

d. Place the research needs in a priority such that the expected results respond to the operational needs.

The guidance in addressing the above objectives is to limit comments to the control of waterhyacinth, Eurasian watermilfoil, and hydrilla. We know that there are other aquatic plant problems, but for right now we have to concentrate on these three species. In addition, do not bias the identification of research approaches, or priorities, by considering estimated costs of conducting the effort. The burden of determining how to achieve the goals within the limited resource

environment rests with the Corps of Engineers management after considering your recommendations.

Group Chairmen Reports and Discussions

Chemical Control Group, Dana R. Sanders

In our meeting this morning we first identified general goals of the Corps' chemical control technical development program, which are:

a. To provide Districts with efficacious herbicides for control of waterhyacinth, hydrilla, and watermilfoil.

b. To determine the effects of the herbicide on the ecosystem into which it is placed and vice versa.

c. To develop and provide Districts with more efficient methods of delivering herbicides to aquatic ecosystems.

The gaps in chemical control technology development are discussed in the following paragraphs.

Conventional herbicides. Concerning waterhyacinth, someone asked if there is any evidence that waterhyacinth builds up resistance to 2,4-D; while the consensus was that seasonality is more important and genetic resistance is not developing, perhaps we should consider this for future work. It was suggested that additional studies on carcinogenicity and teratogenicity of 2,4-D are needed. It was suggested that BEE formulations should be registered; this won't be pursued until an EPA hearing on 2,4-D.

Someone suggested that EPA should fund these 2,4-D studies.

Other compounds also should be considered; some mentioned were Velpar, fenac, metribuzin, and hexazinone.

Concerning hydrilla, currently available herbicides include Aquathol K-copper, diuron, Hydrothol 191, and Hydout.

Lars Anderson stated that there is a real problem in that few chemicals are efficacious on hydrilla in moving waters and registration of any that are efficacious is much more difficult.

Other problems involve more effective application of herbicides, such as bottom placement.

Experimental compounds on hydrilla include fluridone (Eli Lilly submitted an experimental use permit (EUP) petition in October 1978) and fenac of Amchem.

One of the problems we have is how to retain these chemicals long enough to achieve a lethal dose exposure. It was suggested that we get with people who deal with controlled-release herbicides and spray additives and plan investigations of this problem.

Other experimental materials mentioned were hexazinone (Dupont) and terbutryn (Ciba-Geigy).

I mentioned that the APCRP posture is to assist chemical companies in obtaining data required for registration, and that we are actively involved in some of these efforts. The basic responsibility lies with the chemical company and we only become involved when the company shows commitment.

Concerning Eurasian watermilfoil, the Corps needs to provide its people with information on what chemical is labeled for what use and where this label is applicable.

Bob Barry suggested a need for an estimate of acreage of various aquatic weeds to give chemical companies an idea of market potential.

Leon Bates briefly described the Federal Aquatic Plant Working Group's survey of aquatic weeds across the United States (in which the Corps is involved).

Kerry Steward suggested that we probably will find that the best type of herbicide for hydrilla control is one that is persistent, due to a need for control of regrowth from tubers.

I described our perception of steps required for registration of an aquatic herbicide and then noted that we are engaged in efforts with several herbicides at various points in this process.

Controlled-release herbicides. One question that came up was to determine EPA's attitude toward controlled-release herbicides. Tom Jackson suggested a real problem with the herbicide being in the water column for long periods of time.

Frank Harris suggested more emphasis on phytozone treatment. Responding to the question of physical vs. chemical systems, Harris

suggested that chemical systems, though harder to register, are more effective systems.

George Janes stated that EPA should be more favorable to consideration of controlled-release herbicides than conventional forms.

I mentioned that our attitude toward controlled-release herbicides has not changed, but that in future years we need to get into the field and obtain conclusive proof of the merit of this approach. This will be accomplished by EUP application and subsequent field testing by the Corps, cooperators, and/or contractors (hopefully beginning in FY 79).

Spray additives. Two problems were identified in this category. One of these is the use of spray additives (such as Nalco's products) to decrease drift and allow more actual field application time (as in the Jacksonville District).

The second problem is the possibility of using spray additives to decrease dosage rates.

Application technology. A lot of the application problems seem to be with people. Leon Bates suggested the need for a black box approach to herbicide placement at different depths.

John Gallagher suggested the need for an effective blower system for application of granular herbicides without breaking the granules.

Dwight Baillie and others suggested the need for more effective guidance systems for herbicide application.

Kerry Steward suggested the need for improved ability to determine treatment area size and biomass.

Ernie Hesser suggested the need to look at ways to better train applicators.

Since most of these suggestions, except Steward's and Hesser's, deal with mostly mechanical engineering problems, a suggestion was made that we go to industry for expertise in these areas.

Plant growth regulators. This is a new area and study is needed:

a. To determine the ability to retard growth in submersed species.

b. To change resistance of plants to herbicides and possible biocontrol agents.

c. To regulate autofragmentation in watermilfoil.

d. To restrict or prevent tuber formation in hydrilla.

Other problems mentioned included a need for improved interaction with EPA to speed up the process of registration of most compounds.

It was suggested that an immediate solution is needed and that we shouldn't have to wait so long before control options are available. In this regard, Mary Toohey of the Washington Department of Agriculture suggested greater utility of the FIFRA provision for State labeling (24C). Also suggested were possible exemptions from registration since State labeling is a rapid process in many instances.

A representative of the Fish and Wildlife Service suggested a greater need for determining long-term effects of other than the target species, both plants and animals.

Another suggestion was for studies of synergistic effects of chemicals, forms of pollution, and environmental factors.

We really didn't have ample time to address research approaches in detail. Two general points in this regard were made:

a. There is a need for addressing research approaches problem by problem, relying on the available expertise wherever it is to be found.

b. In testing programs, a regimen should be closely followed utilizing those agencies, labs, etc., best equipped and most knowledgeable to obtain the desired results.

Priorities. Priorities were established in the following order:

a. Additional herbicides for hydrilla control, both static and flowing water.

b. Availability of currently registered chemicals for widest use through State registrations, etc.

c. Field testing and product development of controlled-release herbicides.

d. Spray additive studies to reduce drift and decrease required quantities of herbicides.

e. Improved application technology.

f. Several environmental effects of herbicides on the environment (other than those required for registration purposes).

Chemical Control Group attendees

Lars Anderson, USDA-AR, Denver, CO

W. R. Arnold, Lilly Research Laboratories, Boynton Beach, FL

Dwight D. Baillie, British Columbia Ministry of Environment, Canada

Bob Barry, University of Southwestern Louisiana, Lafayette, LA

A. Leon Bates, Tennessee Valley Authority, Muscle Shoals, AL

Richard K. Blush, USAE Division, Lower Mississippi Valley

Ed Bowles, Pennwalt, Fresno, CA

Letha Coenen, Pennwalt, Tacoma, WA

Mike Colbert, Nalco Chemical Company, Oak Brook, IL

Dick Comes, USDA-SEA-AR, Prosser, WA

Douglas Darlis, A-1 Service, Tacoma, WA

Johnnie Frizzell, Pennwalt, Prattville, AL

Charles Fulmer, King County, Seattle, WA

John Gallagher, Union Carbide Agricultural Products Company, Ambler, PA

Bill Gildroy, Jr., Cascade Spraying Service, Lake Stevens, WA

Wm. L. Gildroy III, Cascade Spraying Service, Lake Stevens, WA

Lou Guerra, Texas Parks and Wildlife Department, San Antonio, TX

Frank W. Harris, Wright State University, Dayton, OH

Ernie Hesser, USAE District, Walla Walla, Walla Walla, WA

Tom Jackson, US Fish and Wildlife Service, Denver, CO

John Johnson, Washington Tree Service, Seattle, WA

Obren Keckemet, Pennwalt, Tacoma, WA

Donald Lee, Louisiana Department of Wildlife and Fisheries, Baton Rouge, LA

Danny H. Lewis, Southern Research Institute, Birmingham, AL

Louis Marquis, USDA-SEA-AR, Prosser, WA

Chester O. Martin, USAE District, Galveston, Galveston, TX

Emory McKeithen, Union Carbide Agricultural Products Company, Jackson, MS

Elbert E. Miller, Queen City Yacht Club, Bellevue, WA

Bill Moore, Pennwalt, Winter Garden, FL

W. K. Morris, Oklahoma Water Research Board, Norman, OK

P. L. Poulos, Velsicol Chemical Corporation, Chicago, IL

Julian J. Raynes, USAE Division, South Atlantic, Atlanta, GA

Timothy Redden, USAE District, Seattle, Seattle, WA

Dana R. Sanders, Sr., USAE Waterways Experiment Station, Vicksburg, MS

R. A. Shiverey, Washington State Parks, Wenatchee, WA

Harish Sikka, Syracuse Research Corporation, Syracuse, NY

Kerry Steward, USDA, Fort Lauderdale, FL

Mary Toohey, Washington Department of Agriculture, Olympia, WA

Allan L. Young, Bureau of Indian Affairs, Portland, OR

Biological Control Group, Russell F. Theriot

Insects. Discussion began with Ted Center, who had given the state-of-the-art talk on insects, who gave the group his views on what the technology gaps were in the insect research. These are:

a. Need for a foreign search for insects on Eurasian watermilfoil and hydrilla.

b. Need to know the effects of competitive interaction between two or more insects and/or insects and pathogens when released on the same target species.

He further stated that although not gaps in research, the following are gaps that are very important to the overall program of biological control of aquatic plants:

a. Identify the who, how, and where of rearing and distribution of insects used for biocontrol.

b. Identify new guidelines of specificity requirements concerning insects introduced on submersed aquatic plants.

He stated that after studying several insects thought to have some merit in the control of submersed plants, none of these insects appear to be host specific. It appears that submersed insects feed on several aquatic plants. In the past, insects have not been cleared for introduction in the United States (for instance on alligatorweed and waterhyacinth), if they were not considered to be host specific to the target plant. He felt that if we were ever going to get an insect introduced on a submersed aquatic plant we would have to test this host specificity requirement and have these constraints on host specificity relaxed.

I mentioned that after talking to several people working in the field of aquatic plants, there seems to be two philosophies about the introduction of insects on exotic plant species:

a. Some people feel that after an insect is released from quarantine it can be released in several areas and will spread and become effective on its own.

b. Others believe that most of these insects must be managed to some extent. This involves monitoring populations and supplementing them at some interval.

I stated that I believe the latter, that more needs to be known about population dynamics, etc., the things that will enable us to determine where, when, how, and how many of these organisms are needed for control.

Bob Lazor stated that he thought this was true and said that the nature of each insect would determine the type of distribution needed. He said that there was a need to identify which agency is responsible for the distribution of these insects. He said the information derived from the population studies could be used to establish guidelines for using insects and produce a "biological" label analogous to the chemical label.

Dr. Gary Buckingham said he did not think there were two philosophies, that everyone agreed that this additional work should be done; it's just that no one has yet to do it. He felt that USDA's attitude was that water weeds did not fall under their responsibility.

Dr. Freeman stated that we need additional information to determine when and where insects will work and that, in most cases, this has not been done and there will not be enough time to enable us to predict the cycling of these insects in the field prior to a release. He suggested that the rearing and dissemination of insects could be done by extension type organizations. He suggested that alternatives to this were to turn it over to private interprise or let the Corps or other Government organizations do it.

<u>Pathogens</u>. Since time was a factor, I asked Dr. Freeman to start a discussion on pathogens by identifying the technology gaps as he saw them. He listed the following:

a. Basic research on host-parasite relationships.

b. The possibility that plants can become resistant to the control agent.

c. Operational type experimentation which would include mass production of inoculum and development of applicable equipment, etc.

d. Additional foreign and domestic search for pathogens on the problem species.

e. A major effort for studying pathogens on submersed plants.

Dr. Templeton said we need to encourage more research on the basic biology of pathogens, that this knowledge would help in the use and application of the pathogens on an operational scale.

Dr. Freeman said that the regulation of pathogens used for control needs to be cleaned up, that guidelines were needed.

Dr. Kenny from Abbott Laboratories said that we should move slowly and not force EPA into general guidelines and to let them work case-by-case.

Dr. Freeman also mentioned that Fusarium, a rust, is being studied for control of hydrilla in quarantine. He also expressed a need for searching for pathogens which will affect Eurasian watermilfoil.

Dr. Buckingham said that the matter of selection of pathogen resistant plants should be investigated.

Dr. Peter Frank stated that we may need to show some control over these pathogens being used to kill aquatic weeds.

Dr. Freeman said that before any pathogen would be released for use with a label that it would have to be shown that it could be controlled chemically.

Fish. I then asked Bob Lazor to begin the discussion on the use of fish for the control of aquatic plants. He listed the following:

a. The effects of the white amur on native vegetation and native fisheries.

b. An ability to determine biomass of submersed vegetation that is less labor intensive than the present system.

c. Methods for selective removal of white amur from water bodies after control is achieved.

I mentioned that I thought we needed methods to remove white amur but removal should not be part of an operation plan. It would be easier to have a lower stocking rate initially and add fish as needed rather

than introducing a very large number of fish and trying to remove them. This means we need a better predictive capability.

Dr. Kathy Ewel said more research is needed concerning the food chain in different waters; she said the response of these systems would be different from the introduction of the white amur because the food chains are different and are not well understood.

Dr. Seaman said there was a need to tie limnology in general to the effects of the white amur.

Dr. Tom Crisman said the problem is excess nutrients in the system. More work needs to be done in prevention of nutrient influx and what types and how much vegetation is desired to act as a nutrient sump.

Scott Hardin said that there was a need to predict the regrowth of vegetation after control is achieved.

Dr. Seaman said a study to determine the social impact of the fish should be undertaken; he said that educating people to the fact that trade-offs will have to be made if they want good weed control is needed.

Priorities. The following is a summary of the discussion. The major biocontrols are separate. Technology gaps and studies in order of priority for the next 2 years:

Insects

a. Management of data of insects; this needs to be done between release from quarantine and implementation of operational plan (field evaluation of Samoedes).

b. Foreign search for insects on hydrilla and Eurasian watermilfoil.

c. Rearing and distribution of insects.

d. Competitive interaction between two or more insects and/or insects and pathogens when released on the same target species.

Pathogens

a. Field demonstration of insects and pathogens on waterhyacinth.

b. Host-parasite relationships.

c. Foreign and domestic survey of pathogens on hydrilla and watermilfoil species.

d. Guidelines for use on pathogens for biocontrol.

Fish

a. Consumption rates of white amur greater than 15 lb.

b. Additional basic data on the effects of the white amur on native vegetation and native fisheries.

c. Studies on effect of food chain after removal of vegetation.

d. Increase of predictive capabilities using basic data derived from Items a and b.

e. Techniques for selective removal of white amur.

Biological Control Group attendees

Ron Baer, USDA-SEA-FR, Stoneville, MS

Barbara Blau, Washington State Department of Ecology

Leonce Bonnefil, Department of Natural Resources, San Juan, PR

Gary Buckingham, USDA-SEA-FR, Gainesville, FL

Ted Center, USDA-SEA, Fort Lauderdale, FL

Thomas L. Crisman, University of Florida, Gainesville, FL

Katherine C. Ewel, University of Florida, Gainesville, FL

Peter A. Frank, USDA-SEA, University of California, Davis, CA

Ed Freeman, University of Florida, Gainesville, FL

Kurt D. Getsinger, Clemson University, Clemson, SC

J. Steve Godley, University of South Florida, Tampa, FL

Scott Hardin, Florida Game and Fresh Water Fish Commission, Orlando, FL

Donald S. Kenney, Abbott Laboratories, Long Grove, IL

Floor Kooijman, University of Florida, Gainesville, FL

Robert L. Lazor, Florida Department of Natural Resources, Tallahassee, FL

Roy McDiarmid, University of South Florida, Tampa, FL

William T. Nailon, USAE Division, Southwestern, Dallas, TX

Larry E. Nall, Florida Department of Natural Resources, Orlando, FL

E. A. Seaman, Bureau of Reclamation, Washington, DC

Cline Sweet, Bureau of Reclamation, Soap Lake, WA

George E. Templeton, University of Arkansas, Fayetteville, AR

Russell F. Theriot, USAE Waterways Experiment Station, Vicksburg, MS

Cesar Von Chong, Panama Canal Company, Gamboa, Canal Zone

Mechanical Control Group, P. A. Smith

The Corps of Engineers has been in the mechanical control business for many years; however, we have not documented the data derived from this effort very well. Therefore, today we are still using systems similar to those used 50 years ago. The WES has been in mechanical control work for the past 3 years. We realized very early in the game that there were insufficient data to design a mechanical control system; therefore, we initiated an ongoing data collection program in 1977.

The state of the art has not progressed very far.

As charged, the following conclusions were reached by our working group:

a. Gaps - not in particular order.

(1) Capital investment intensive.

(2) Equipment single in purpose.

(3) Collects fish.

(4) Site specific.

(5) Disposal methods.

(6) Mechanical failure.

(7) Not yet cost-effective.

(8) Material handling technology very limited.

(a) Towing.

(b) Conveying - water/vehicle interface.

(c) Baling.

(d) Blanching.

(e) Transportation over long distance in harvested state.

(f) Low-energy systems.

(9) Modeling programs.

b. Research efforts.

(1) Material handling - same items as in a(8).

(2) Regrowth rates - need to compile these data from various persons and areas.

(3) Disposal effects.

(a) On land - nitrate poisoning, etc.

(b) In water - dissolved oxygen and other water-polluting factors.

c. Alternative efforts - discussed very briefly, nothing firm.

d. Research priority - in order to keep us from repeating the Corps' past record, we must keep a basic research effort ongoing in mechanical control at WES.

e. Technology acquisition and dissemination to interested persons.

Technology transfer.

(1) Material handling - this can be done in small RFP's and contracts studying the individual problems (baling, conveying, transporting).

(2) Disposal of plants - land, water, feed, mulch.

(3) Cost-effectiveness of mechanical control.

(4) Complete removal of submersed plants; hydrilla/milfoil.

Mechanical Control Group attendees

Greg Armour, Ministry of Environment, BC, Canada

Larry O. Bagnall, University of Florida, Gainesville, FL

Orrin D. Bechwith, USAE Division, North Pacific, Portland, OR

C. Brate Bryant, AquaMarine Corporation, Waukesha, WI

Dave Dupee, USAE Division, New England, Waltham, MA

James K. Ely, A-1 Spray Service, Inc., Tacoma, WA

E. E. Jennens and wife, JEN-Industries LTD., Kelowna, BC, Canada

Dick Koegel, University of Wisconsin, Madison, WI

Thomas Kelpin, Allied Aquatics, Shreveport, LA

Bob Langford, AquaMarine Corporation, Victoria, BC, Canada

Bob Leonard, Bureau of Reclamation, Ephrata, WA

James T. McGehee, USAE District, Jacksonville, Jacksonville, FL

John Neil, Limnos Ltd., Toronto, Canada

Alexander Nikolson, Arundo Ltd., Belle Chasse, LA

Bob Rawson, USAE District, Seattle, Seattle, WA

Perry A. Smith, USAE Waterways Experiment Station, Vicksburg, MS

Jack K. Stoll, USAE Waterways Experiment Station, Vicksburg, MS

Bill Thompson, USAE District, New Orleans, New Orleans, LA

Integrated Control Group, E. E. Addor

Integrated control is a useful concept at the research area programming level. In fact, it appears that it is essential to:

a. Mixed organisms.
b. Behavior modifications.
} biological, not integrated

c. Mechanical devices reduction of bionics.

d. Mechanical or other procedures in special distribution.

It is a combination of two or more strategies for control of one or more target species on a given hydrosystem, used simultaneously or sequentially in time or space.

Application depends upon good knowledge of the ecosystem (biocommunity), including physical and physiological interaction among target species, nontarget species, potential controlling organisms, and their physical environments. By implication, there is significant overlap with other research areas; in particular, the biology of organisms as it relates to the aspects of biological control involving mixed agents and behavior modifications.

Existing methods include:

a. Biological.

(1) Insects.

(2) Fish.

(3) Pathogens.

(4) Competitive plantings (spikerush) (fertilization for algae growth).

b. Mechanical.

(1) Booming and fencing.

(2) Harvesting.

(3) Cutting.

(4) Destroyers.

c. Chemical.

(1) Herbicidal.

(2) Growth regulators.

d. Environmental manipulation.

(1) Drawdown (water fluctuation).

(2) Flushing (flooding, saltwater).

(3) Erosion and eutrophication control.

e. Preventive maintenance, public education.

Research needs determined by the group include:

a. Surveying existing techniques for given species including projects and results.

b. Identifying environmental relations and potential impacts of techniques.

c. Identifying physiological aspects of plant life cycle (phenology) that lend themselves to integrated control.

d. Relating ecology of target species to ecology of other (valued) species in the system (identify people problem).

e. Identifying methods which show promise for integration.

f. Conducting demonstration projects of promising integrated methods.

Data gaps include:

a. Characteristics of target species that lend it to integrated control.

b. Identification of priority conflicts (people and environmental concerns).

c. Synergistic and antagonistic effect.

d. Timing of application.

e. Efficiency of combinations.

f. Effects on nontarget values.

Conclusions of the integrated working group (emphasis by species) include:

a. Waterhyacinth - most methods of control well advanced; problem at present appears to be one of identifying opportunities to improve control by integrated methods.

b. Watermilfoil - use the program developed by TVA, British Columbia, and Ontario, Canada, as a model for application in other problem regions.

c. Hydrilla - present status of work on this species suggests possible integration of chemical and mechanical methods; possible use of competitors is a potential for immediate research.

The status of the Interagency Working Group on integrated management systems is that the group is developing a report which includes current control methods and research needs.

Integrated Control Group attendees

E. E. Addor, USAE Waterways Experiment Station, Vicksburg, MS

Joe Baliciunas, University of Florida, Fort Lauderdale, FL

LTC Philip E. Custer, Panama Canal Company, Canal Zone

Dick Duncan, USAE District, Portland, Portland, OR

Russ Dunst, Wisconsin Department of Natural Resources, Madison, WI

Mark Follett, USAE District, Seattle, Seattle, WA

Alden Foote, USAE District, Walla Walla, Walla Walla, WA

Terry Goldsby, Tennessee Valley Authority, Muscle Shoals, AL

Joe Joyce, USAE Disrict, Jacksonville, Jacksonville, FL

David Keiser, Olympia, WA

Glen Montz, USAE District, New Orleans, New Orleans, LA

Peter Newroth, Ministry of the Environment, Victoria, BC, Canada

Gene Otto, Bureau of Reclamation, Denver, CO

Sharon Parker, L & V Farm Sales, Los Entos, CA

Chuck Quimby, USDA, Stoneville, MS

Ray Wehholt, Camron Corporation, Seattle, WA

MEETING SYNOPSIS

by

J. Lewis Decell

Following our central thrust which was to assess the state of the art and look at the capabilities and identify some needed directions for our future programs, we touched on a lot of areas, and I'm just going to name a few.

We talked about the Corps' mission in aquatic plant control. We discussed in some length the research needs system. Technology transfer was discussed and we talked about chemical control, biological control, mechanical control, integrated control, operational management, and, of course, research needs.

Two Federal working groups met in conjunction with this meeting and discussed several points and projects that, if successfully implemented, are going to be of value to everybody concerned in aquatic plant control, and I mean State agencies, Federal agencies, and otherwise.

We talked about early recognition, and prevention was stressed. Public fear was expressed relative to anticipating how successful we would be now that the public has become cognizant of the problem. The need for action on almost a daily basis by people who are engaged in the "war of the weeds" was mentioned.

The need for a political basis for action, something we lack at some levels, was discussed. The central concern for the environment was continually and rightfully discussed relative to every method of control, as was the need for education programs at all levels extending all the way through the public sector.

We identified confusion among outselves within the Corps as to what we're doing; we clearly defined in our program review that we weren't up to date on just what was ongoing in the various Districts. We concluded that we need to get our act together among ourselves and do a better job of technology transfer. We need to present a united front and give the program the attention it needs in this competitive

arena of the budgeting process. I think we can do a better job there. The program itself is not being given the internal attention commensurate with the attention that the public is giving the problem. At next year's meeting I think we're going to give more emphasis to our researchers for their presentations of just what they're doing. Our operational people will probably get several forums to tell us how they're using this technology, if we are in fact transferring the technology to them. That's not to say we won't have any panel discussions, but they will probably be on critical issues.

During the process of these meetings, we identified the need for about 15 specific additions to our information bulletin to enlighten people about things that are being done. We're going to start getting some of these bulletins out on a monthly basis starting as soon as we can.

We've accomplished a lot, but I think that we'll never be able to rest on our laurels as long as we've got even a potential for an aquatic plant problem. In case you're interested in a few facts and statistics, we spent about 18 hours in actual meetings in this room. We signed some 171 attendees. If 80 percent of those were actively engaged in this context, we've spent about 2500 man-hours talking about aquatic plant problems and what we should do about them. We provided the opportunity for about 7500 hours of other activities that went on after we adjourned every day.

We were criticized, also, so in summarizing here I'd like to go through five or six things of criticism. We were criticized for starting too late each morning, and we were also criticized for starting too early each morning. We were criticized for not providing enough time for panel discussions, and we were criticized for spending too much time on panel discussions. We were criticized for having too many activities associated with the business aspect of the meeting, and the people who complained about starting too early each morning complained about not having enough activities. We had a complaint that we did not have enough slide shows, and the same people complained about not getting enough sleep during the 3 days. We had complaints about not having enough

Corps of Engineers people here, and I had a complaint that there were too many Government employees walking around.

So, what's the net effect? I think the bottom line is that, thanks to you and your participation, we had an informative and productive meeting. We're looking forward to seeing everybody in Tulsa, Oklahoma, and if the meeting changes from October, we'll give you an advance notice. If there are no more questions, comments, or announcements, then the 13th Annual Meeting will stand adjourned.

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APPENDIX A: SUMMARY PROGRESS REPORTS

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EVALUATION OF CHEMICALS FOR AQUATIC PLANT CONTROL

Principal Investigator: K. K. Steward
R/A 12-14-700-992

Objective

The purpose of this project is to expand evaluation research on the use of chemicals for aquatic weed management. New herbicides or growth regulators need to be discovered for the selective removal or growth regulation of different species of aquatic plants.

Approach

Floating and emergent aquatic plants are established in 12-liter, polyethylene-lined containers for one to four weeks before being treated. Replicated treatments are applied on an area basis by use of a small atomizer after which the plants are moved to a greenhouse for periodic evaluation for phytotoxicity.

Submersed aquatic plants are set up in 3.8- or 19-liter jars by planting apical sections in small plastic pots of sand-soil mix. After the pots are placed in the appropriate jars, they are allowed to become established for approximately one week before being treated. Replicated treatments are made by injecting the required solutions into the water with a hypodermic syringe.

Treatments in outside aquaria involve either circular, vinyl-lined containers (manufactured for use as swimming pools) or rectangular-shaped concrete boxes covered with two coats of white epoxy paint on the inside. When used for submersed plants, apical cuttings are planted at a density of 428 stems per square meter. When used for floating species, the plants are allowed to completely cover the surface area prior to treatment.

Current Status

Treatments applied to torpedograss in the greenhouse indicate that plants rooted in soil and partially submerged are more resistant to control than plants which were cultured hydroponically to simulate floating mats.

The addition of the adjuvant SA-77 did not alter the efficacy of selected treatments to rooted plants except for the 6.7-kg/ha glyphosate treatment.

Greenhouse evaluations with waterhyacinth showed that, while effective at the 1-kg/ha rate, several fenac salts were not as effective as the reference 2,4-D which produced greater injury and faster response.

The most effective herbicide evaluated in outside aquaria against waterhyacinth was hexazinone. It was more effective than the reference 2,4-D. The growth retardant EL-509 was continuing to supress growth of waterhyacinth at 23 weeks. Tests are currently in progress evaluating integrated control utilizing EL-509 and Neochetina.

Combinations of diquat and iron were compared with diquat and copper for efficacy against hydrilla in the laboratory. The addition of iron to 0.02-mg/ℓ rates of diquat appeared to increase the efficacy of the treatment toward hydrilla while the addition of copper decreased the injury rating.

Evaluations of the adjuvant properties of SA-77 were confounded by the use of phytoxic levels of the adjuvant as all treatments containing the adjuvant were controlled. Tests are under way to determine threshold concentrations of this compound.

Evaluations of ten experimental fenac formulations have identified several with efficacy toward either hydrilla or southern naiad.

Terbutryn was not effective in inhibiting the sprouting of hydrilla tubers but was moderately toxic toward emerging shoots. EL-171 (fluridone) was moderately effective against hydrilla after 28 weeks in outside aquaria. A 2-mg/ℓ rate had produced 88% control by this time.

The growth retardant EL-509, at a rate of 1 mg/ℓ, prevented regrowth from hydrilla rootstocks for approximately 24 weeks. Retreatment did not prevent further regrowth. Untreated rootstocks had reached the surface of the outside aquaria approximately eight weeks after the initial treatment.

Evaluation for the possible synergism toward hydrilla between combinations of fenac and copper was performed in outside aquaria. The

most efficacious treatment was the 2-mg/ℓ combination which produced nearly complete control and achieved the greatest reduction in biomass.

Hexazinone was applied to hydrilla in outside aquaria. The 1.0-mg/ℓ treatment produced an average of 95% control by three months and 100% control by six months. The lower rate, 0.5 mg/ℓ, produced 95% control after five months and 100% control by seven months.

Propagule production was greatly reduced by both treatment rates of hexazinone - zero propagules from the 1.0-mg/ℓ rate and eight propagules from the 0.5-mg/ℓ rate as compared to 1092 propagules for the 0.0-mg/ℓ treatment.

Phytotoxic residues of hexazinone were found in both treatment rates after eight months by bioassay with hydrilla cuttings.

Field evaluations were also made with hexazinone against hydrilla. The most effective treatment was 3.4 kg/ha, producing effective control by two months and maintaining nearly 100% control through 12 months.

The 6.7-kg/ha rate produced nearly complete control by two months but regrowth was rapid by four months.

Application of a 2-mg/ℓ rate of granular formulation of fenac was effective against hydrilla in the field. Hydrilla control gradually increased from 50% at two months to 99% after eight months.

Both terbutryn and hexazinone were effective against chara in outside aquaria. An 0.2-mg/ℓ treatment rate of terbutryn produced 100% control after 14 weeks, while an 0.5-mg/ℓ treatment rate of hexazinone produced 100% control after six weeks.

Significant Accomplishments

Hexazinone has been shown to be effective as long lasting control for hydrilla both in outside aquaria and field tests. Fenac has also been found to be effective for lasting control of hydrilla in the field.

Fenac and copper have been shown to be more effective against hydrilla than either compound alone.

The growth retardant EL-509 has been shown to effectively inhibit hydrilla regrowth from clipped stems for up to 24 weeks.

EVALUATION OF CONTROLLED-RELEASE HERBICIDES IN OUTDOOR POOLS

Principal Investigator: J. A. Foret
Associate Investigator: Robert Barry

Modification of Contract No. DACW39-74-C-0074

Objectives

The objectives of this study are as follows:

a. To test three controlled-release herbicide formulations for efficacy in control of five aquatic weed species which cause serious problems in water systems throughout this country.

b. To obtain data on herbicide residues during the course of the experiment that might serve as a basis for interpretation of weed control data obtained in a above and which might also provide an insight as to residue levels and release rates to be expected under field test conditions.

Approach

The controlled-release herbicides tested were CBL 14 ACE-B, a rubber-2,4-D combination containing 18.7% butoxyethanol ester of 2,4-D; CBL E51, a rubber-copper-sulfate monohydrate combination containing 17% CU^{++} (both CBL formulations provided by Creative Biology Laboratory of Barberton, Ohio); and a fenac-polyethylene compound developed by Dr. Frank Harris of Wright State University, Dayton, Ohio.

These herbicide formulations were tested in plastic-lined pools having dimensions of 3 m square by 0.5 m deep. Tests were conducted during the summer and fall of 1976 and 1977. The aquatic weed species included in the pools were egeria (*Egeria densa* Planch.), hydrilla (*Hydrilla verticillata* Royle), Eurasian watermilfoil (*Myriophyllum spicatum* L.), coontail (*Ceratophyllum demersum* L.), and waterhyacinth (*Eichhornia crassipes* (Mart.) (Solms).

Evaluation of weed control was made both by visual rating and by determining the dry weights of the biomass produced by each weed species. Counts of subterranean tubers on hydrilla roots were also made at the end of the 1977 experiment.

Current Status

The pool phase of this experiment was completed during the fall of 1977 and analyses of water samples were completed during the winter of

1977 and spring of 1978. A detailed report of this research project has been completed and submitted to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Significant Accomplishments

The experiments described herein showed that controlled-release formulations of 2,4-D BEE, copper sulfate, and fenac acid at the appropriate rates were effective for abatement of aquatic weed growth and in some instances complete eradication of test species. Degree of weed control was a function of herbicide sensitivity of the target species and concentration of the herbicide in the experimental pools.

Each of the three controlled-release formulations was effective on some of the test species and merits field testing to determine effectiveness under actual control situations. The rubber-2,4-D formulation completely eradicated Eurasian watermilfoil at rates as low as 5 ppm; more extensive testing for this use is indicated. Other aquatic species showed only slight sensitivity to the 2,4-D formulation. Careful monitoring of field experiments is indicated, since 2,4-D residues in excess of the 0.1 ppm permissible level for potable water were found at application rates as low as 5 ppm.

The polyethylene-fenac formulation at the 60-ppm rate eradicated egeria, Eurasian watermilfoil, coontail, and waterhyacinth and provided significant abatement of hydrilla growth and subterranean tuber development. The broad spectrum of herbicidal activity over a range of application rates demonstrates the need for future field testing of this formulation.

The rubber-$CuSO_4$ formulation proved most effective at the higher application rates of 50 and 100 ppm for abatement of egeria, hydrilla, Eurasian watermilfoil, and waterhyacinth. Coontail was eradicated from the pools at these rates in 1976 by all treatment levels of rubber-$CuSO_4$ formulation. This formulation also is worthy of field testing. Copper residues exceeded the 1 ppm tolerance for potable water for a short

period where the 100-ppm application rates were used. Careful monitoring of any field tests for copper residues would be imperative where application rates of 100 ppm are used.

The logical step beyond these pool studies is field testing the controlled-release herbicides. Data obtained from this research can serve as a pattern for establishing rates of application and for monitoring residues in future field testing operations.

DEVELOPMENT OF CONTROLLED-RELEASE HERBICIDES

Principal Investigator: G. A. Janes

Contract No. DACW39-76-C-0029

Objective

The objective of this research is to provide model controlled-release compounds and evaluate the efficacy of the controlled-release approach to the control of aquatic weeds.

Approach

Chemical control is currently accomplished by a single acute dose applied up to the maximum acceptable level. There is no presumption that this is the most effective rate. It is the method of choice because to date it has been the only economically feasible method. Occasionally, a single follow-up treatment is used, but the cost-intensive application procedures prohibit a systematic dosing regime and, therefore, they have not been evaluated.

Controlled release, by contrast, provides a means by which an infinite number of potential dosing rates can be considered. The discipline frequently refers to long-term or slow release, but these do not encompass the full range of controlled-release potential. There now exists a reason for looking at the optimum dose rates since they are technically possible and economically feasible with controlled-release technology.

Elastomeric materials have been shown to be particularly promising as controlling carriers for bioactive materials. Commercial examples of the successful use of this technology include: B. F. Goodrich "Nofoul," a marine antifouling material that has exhibited more than 10 years effective service life and Shell "No-Pest Strip," the first of the controlled-release insecticides.

Chemicals with known efficacy against pest aquatic weeds are incorporated in various elastomer bases with controlled-release value. The materials are adjusted by variations in ingredients and changes in mixing and curing according to the compounders art to achieve a homogeneous matrix.

Laboratory evaluation by bioassay and chemical techniques is conducted on promising combinations to determine efficacy of the compound and provide dose rate parameters for larger scale pool and field tests.

Promising compounds are evaluated for processibility on production equipment, and the required modifications are fed back to the laboratory for evaluation of their effect on release rate and efficacy.

Current Status

Phytotoxic chemicals have been successfully incorporated into controlled-release compounds that will serve as model compounds for field evaluation of the controlled-release concept of aquatic weed control.

The following is a partial list of active agents and carriers that have shown promise:

Elastomer Carriers

Styrene-butadiene copolymer (hot polymerized)	Cis polybutadiene
	Polyisoprene
Styrene-butadiene copolymer (cold polymerized)	Ethylene-propylene-diene Terpolymer
Synthetic natural	

Active Agents

Fenac	Silvex
Diquat	Endothall
2,4-D Acid	Fenuron
2,4-D BEE	Copper Sulfate

The relative susceptibility of eight aquatic weed species to chronic doses of various herbicides has been evaluated. The results indicate that control is possible at ultra low levels.

Scale tests have been conducted on controlled-released formulations of 2,4-D BEE and $CuSO_4$, indicating that laboratory control of target plants can be achieved in larger scale evaluations. Several model

controlled-released compounds have been evaluated for compatibility to production equipment processing.

Significant Accomplishments (1978)

Fate of elastomer carriers

The need to determine this has been strongly indicated by the Environmental Protection Agency and other environmental groups. At the same time there has been no determination of what will be required for registration. Forty-six microenvironments have been established to observe the decay rate of six elastomers in four soil selections. Upon request, these units can be sacrificed to analysis for effect (if any) on the environment.

Downstream transmission

A flowing test system designed and built this year provides for the quantitative comparison of the migration characteristics of conventional and controlled-released herbicides. Organic and inorganic challenges will provide comparative results between different herbicides needed for field evaluations.

Inverse dose response

The inverse dose response was observed with copper sulfate against hydrilla. Previous studies had shown the chronicity effect with continuously applied low doses displaying surprising efficacy compared to the higher standard dose. The inverse response is noted where one low level dose has a greater and more rapid effect on the test plants than a significantly higher (but still low) dose. This response, which has been observed in three of four experiments, could have a profound effect on the feasibility of controlled-release herbicides, particularly if it is found to apply to other plants and/or herbicides.

Field support

Field support is an increasingly important part of the development effort. Information that originally was expected to come from small-scale field tests must be developed in the laboratory due to environmental limitations on fieldwork. Studies include translocation, delivery rate,

and plant density or biomass evaluations to assist in planning and evaluating field tests. A field test quantity of a copper sulfate controlled-release material was produced to demonstrate that the model compounds are not merely laboratory curiosities, but rather are compatible with production capability. Laboratory studies of this production material have provided some valuable data along with the otherwise disappointing field results. Studies show that a surfactant is a useful tool for adjusting buoyancy of a controlled-release material because it has a minimal effect on release rate. Production methods were shown to alter the buoyancy and delivery rate of toxicant.

Delivery rate studies

Delivery rate studies are an outgrowth of loss rate studies. The determining factor in the control of aquatic plants is the delivery of toxicant to the target plants at their most susceptible point. It is increasingly apparent that the position of the controlled-released material in the phytozone and the extent to which target plants and other elements in the environment act as a "sink" for the toxicant greatly affect the efficacy of the herbicide.

Bioassays

This year's efforts to evaluate the potential of various model compounds include the following:

	Diquat	2,4-D Acid	Copper	Fenac	Blanks
Milfoil	X				
Hydrilla	X	X	X	X	
Naid		X			
Cabomba			X	X	
Elodea		X	X	X	X

Several of the toxicants were evaluated against the indicated plants in more than one carrier base or at different loading levels.

DEVELOPMENT OF CONTROLLED-RELEASE AQUATIC HERBICIDES

Principal Investigator: F. W. Harris
Contract No. DACW39-76-C-0016

Objectives

The purpose of this research was to continue the development of the controlled-release aquatic herbicides that were initially prepared under previous Corps of Engineers contracts. The specific objectives of this research were:

- a. To further investigate the copolymerization of 2-acryloyloxyethyl 2,4-dichlorophenoxyacetate (AOE-2,4-D) with methacrylic acid (MAA).
- b. To copolymerize the AOE-2,4-D monomer with a new hydrophilic comonomer, i.e., 2-hydroxyethyl methacryle (HEM).
- c. To determine the release rates of all the new copolymers prepared.
- d. To determine the effect of wetting agents on the copolymers' rates of release.
- e. To prepare 1- to 2-kg quantities of the most promising copolymers for preliminary field testing.
- f. To evaluate new biodegradable matrices for physical systems.
- g. To determine the release rates of all physical combinations prepared.
- h. To prepare 1- to 2-kg quantities of the most promising biodegradable formulations for preliminary field testing.

Approach

Copolymerization of AOE-2,4-D with MAA

In order to obtain additional information regarding copolymer composition, the free-radical reactivity ratios of AOE-2,4-D and MAA were determined by the following procedure. A series of copolymerizations with varying monomer feed ratios were run in methyl ethyl ketone heated at 70°C. The copolymerizations were carried out to low conversions (less than 5%), and the resulting copolymers' compositions were determined by chlorine analysis. The reactivity ratios were calculated

from the resulting data according to the method of Fineman and Ross.

Copolymerization of
AOE-2,4-D with 2-HEM

AOE-2,4-D was copolymerized with different amounts of HEM in refluxing methyl ethyl ketone with azobisisobutyronitrile (AIBN) as the initiator. The molar ratios of AOE-2,4-D to HEM employed were 85:15, 60:40, 50:50, and 40:60. The reactivity ratios of the two comonomers were also determined using the method of Fineman and Ross. In order to determine the effect of molecular weight and cross-linking on the copolymers' rates of release, copolymerizations were also conducted in the presence of multifunctional branching and cross-linking agents.

Effect of wetting agents
on release rates

In order to determine the effect of wetting agents on the copolymers' release rates, the herbicide release rate of a copolymer prepared with a 50:50 molar feed ratio of AOE-2,4-D and HEM was determined in the presence and absence of a commercial wetting agent (Zonyl FSN^{R}).

Preparation of beeswax and polycaprolactone
controlled-release formulations

Granular beeswax was ground and mixed with different amounts of fenac. The mixtures were then heated and stirred to afford homogeneous melts. The melts were allowed to cool in petri dishes. Circular pellets with 1-1/2 cm diameter weighing approximately 0.4 g were cut from the solidified melts with cork borers. Polycaprolactone pellets containing different amounts of fenac and 2,4-D were also prepared by this procedure.

Preparation of chitosan
controlled-release formulations

Chitosan and different amounts of the dimethylamine salt of 2,4-D were dissolved in glacial acetic acid solutions. Various dialdehydes were added to the resulting mixtures to afford cross-linked, insoluble gels. The gels were dried under vacuum to afford dark-brown powders.

Release rate determinations

The 2,4-D copolymers and the chitosan formulations were sieved to obtain a uniform particle size (125 to 400 μ). Three 0.5-g replicates

of each sample were then added to individual 500-ml erlenmeyer flasks containing 300 ml of a boric acid buffer (pH = 8). The flasks were placed in a constant temperature air bath maintained at 30± 0.5°C. The bath was attached to a laboratory rotator that provided slight agitation. The amount of 2,4-D released from the samples was determined periodically by spectrophotometric analysis.

The herbicide release rates from the beeswax and caprolactone pellets were determined by a similar procedure. In these cases, one pellet was added to each erlenmeyer flask.

Current Status

The reactivity ratios for AOE-2,4-D and MAA have been determined to be 0.30 and 1.58, respectively. The reactivity ratios for AOE-2,4-D and HEM have been found to be 0.43 and 2.60, respectively.

Linear copolymers of AOE-2,4-D and HEM have been prepared that contain from 15 to 60 mole % HEM. The copolymers release 2,4-D at rates ranging from 0.3 to 1.5 mg/g of copolymer per day. The rates increase slightly as the hydrolysis proceeds. The copolymers slowly swell in the buffer and eventually go into solution. Branched and cross-linked copolymers of AOE-2,4-D and HEM have also been prepared. Although the branched systems have molecular weights considerably higher than those of analogous linear systems (16,000 compared to 6,000), the release rates of the two systems are not significantly different. The branched polymers also slowly swell and go into solution. The cross-linked system, which swells slightly in the buffer but doesn't dissolve, releases 2,4-D at a fairly constant rate of 2.2 mg/g of copolymer per day.

Wetting agents have been found to effectively wet the copolymers' surfaces. Copolymer particles immediately sink when immersed in a buffer solution containing a surfactant. The herbicide release rate, however, is not significantly different than that observed in the absence of a wetting agent.

Beeswax and polycaprolactone formulations have been prepared that contain 30 to 50% fenac or 2,4-D. The fenac/beeswax formulations release approximately 70% of their herbicide in 60 days. The 2,4-D/polycaprolactone formulations release approximately 70% of their herbicide in 30 days, while the fenac/polycaprolactone pellets release 75 to 95% of their herbicide in 60 days.

The dimethylamine salt of 2,4-D has been entrapped in cross-linked-chitosan matrices. The herbicide, however, is completely released from these systems in 7 to 10 days.

Significant Accomplishments

Reactivity ratios have been determined for AOE-2,4-D and MMA and HEM. Hence, the exact composition of a copolymer prepared with a given monomer feed ratio can be calculated. The monomer feed ratio needed to prepare a copolymer with a desired composition can also be calculated.

The release of 2,4-D from 2,4-D/HEM copolymers has been found to be independent of molecular weight. Relatively constant release rates have been attained by the incorporation of cross-linking in these systems. Wetting agents have been found to aid in the copolymers' dispersal in water while not affecting their release rates.

Beeswax, polycaprolactone, and chitosan have been used in the preparation of biodegradable herbicide formulations. Although these formulations have relatively fast release rates, they may prove useful in improving the efficacy of fenac.

One-kilogram samples of a 90:10 AOE-2,4-D/MMA copolymer and a 50:50 AOE-2,4-D/HEM copolymer have been prepared and sent to Dr. Kerry Steward for preliminary field testing.

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FATE OF FENAC IN THE AQUATIC ENVIRONMENT

Principal Investigator: Harish C. Sikka

Contract No. DACW39-77-C-0021

Objectives

The overall purpose of this project is to assess the role of certain processes which may control the fate of fenac (2,3,6-trichlorophenylacetic acid) in the aquatic environment and determine the toxicity of fenac to aquatic organisms. The specific objectives of the study are:

a. To determine the hydrolysis of fenac.

b. To study photodegradation of fenac in aqueous solution.

c. To examine the sorption and desorption of fenac by sediment.

d. To study the biodegradation of fenac in lake water and activated sludge.

e. To assess the effect of the herbicide on aquatic microorganisms.

f. To determine the toxicity of fenac to fish, *Daphnia*, and algae.

g. To investigate the bioaccumulation and metabolism of fenac in fish.

The results of this study will provide data needed for registering the herbicide for aquatic plant control.

Accomplishments

A summary of the work completed to date and the results are described below.

Hydrolysis

Fenac (2 ppm) was added to sterile distilled water buffered to pH 5, 7, and 9. The herbicide solution was incubated at 10^{o} and $25^{o}C$ in the dark and maintained under sterile conditions. Analysis of the solution after 1, 2, and 3 weeks of incubation did not indicate any loss of the herbicide, suggesting that hydrolosis is not likely to influence the environmental fate of fenac.

Photodegradation

A solution of fenac (2 ppm) in distilled water was irradiated with a 450-watt Hanovia medium pressure mercury lamp fitted with a Pyrex filter to exclude light of wavelength less than 280 nm. No loss of fenac was observed following 36 hours of irradiation, indicating that

direct photolysis is probably not an important pathway for degradation of the herbicide.

Since natural waters are known to contain certain photosensitizers, the photolysis of fenac was examined in the presence of photosensitizers such as riboflavin phosphate (FMN), methylene blue, or commercially available "humic acid." These compounds substantially enhanced the photodegradation of fenac; approximately 75% of the herbicide had been degraded within 24 hours of irradiation. The results indicate that fenac may be photodegraded in an aqueous solution in the presence of materials dissolved in natural waters. FMN-sensitized or methylene blue-sensitized photodegradation of fenac resulted in several products, all with an alteration only in the side chain of the molecule.

Adsorption by fenac by sediment

Adsorption of fenac was determined in four types of sediment (organic muck, reduced clay, unreduced clay, sandy sediment) provided by the U. S. Army Engineer Waterways Experiment Station. A solution of ^{14}C-fenac (2 ppm) was added to sediment-water suspension and the suspension was shaken in the dark. Subsequent to fenac-sediment equilibration, the suspension was centrifuged and the supernatant was counted for radioactivity. The amount of ^{14}C-fenac disappearing from the solution was assumed to be adsorbed by the sediment. The degree of adsorption was expressed as the distribution coefficient Kd, the ratio of the concentration of fenac in the sediment to the concentration in the equilibration solution. The results showed that the Kd values in the sediments ranged between 2.0 and 6.0, suggesting that fenac is not adsorbed by the sediments in significant amounts.

Biodegradation of fenac in lake water and sediment

Fenac was added at a concentration of 2 ppm to 5-gal capacity glass aquaria containing 6 ℓ of lake water and a 2-in. layer of sediment. Aliquots of water were periodically analyzed for the herbicide up to 24 weeks after treatment. The fenac concentration in the water declined rapidly during the first week following treatment. The initial decrease in herbicide concentration was believed to be due to sorption by the

sediment. Subsequently, there was a small decrease, if any, in the herbicide concentration in water up to 20 weeks. Thereafter, the level of fenac in the water decreased at a fairly constant rate and was below 1 ppm after 35 weeks. These findings suggest that fenac is not readily degraded by microorganisms. In view of the large fluctuations observed in these experiments, it is planned to repeat these studies in order to assess the role of microorganisms in degrading the herbicide.

Studies on the anaerobic aquatic metabolism of fenac are in progress.

Effect of fenac on
aquatic microorganisms

Studies are in progress to assess the effect of fenac on the activities of microorganisms in lake water and sediment.

Toxicity of fenac
to aquatic organisms

The 90-hour LC_{50} (median effective concentration) of fenac to Daphnia magna was found to be 28 ppm. The herbicide at 9 ppm inhibited reproduction in Daphnia by about 50%, but had little or not effect on reproduction at 2 ppm. Fenac was not toxic to fathead minnows or rainbow trout up to a concentration of 40 ppm under conditions of a 96-hour static bioassay.

Bioaccumulation, elimination,
and metabolism of fenac in fish

The ability of bluegill sunfish to bioconcentrate fenac directly from water was examined. Using radiometric techniques and continuous flow exposure, bluegills exposed to 2 ppm fenac in the water accumulated minimal ^{14}C residues. Equilibrium levels of ^{14}C in edible portions of the fish were achieved within 6 to 9 days of exposure and between 9 and 13.5 days in nonedible portions. The bioconcentration factor (ppm ^{14}C fenac equivalent in fish/ppm fenac in water) was 0.7 for edible tissue and 2.8 for nonedible tissue. The rate of depuration of ^{14}C residues was measured by transferring exposed fish into flowing, noncontaminated water, with periodic sampling of the fish. The rate of elimination of ^{14}C residues from edible tissue was first order with respect to time, with an elimination rate constant k of 0.050 day^{-1} and a half-life $t_{0.5}$

of 11.5 days. Elimination from nonedible tissue was biphasic. The initial fast phase of elimination (0 to 7 days of elimination) showed $k = 0.120\ day^{-1}$ and $t_{0.5} = 5.8$ days, while the following slower phase (7 to 21 days) showed $k = 0.046$ and $t_{0.5} = 16.4$ days. These results show that fenac is slowly but continually eliminated from the fish after they are removed from sources of contamination and should not present a significant residue problem.

Extracts of exposed fish and of the exposure water were examined by thin-layer chromatography. Only one spot, corresponding to authentic fenac, was detected. Gas chromatographic analysis also showed only fenac.

RESEARCH ON THE BIOLOGICAL CONTROL OF AQUATIC WEED

Principal Investigators: T. D. Center
J. L. Balcuinas

R/A 12-14-700-995

Project A. Release and establishment of *Sameodes albiguttalis*; monitor dispersal; evaluate efficacy.

Objectives

The purpose of this project is to release *Sameodes albiguttalis* at selected field sites in such a manner that the best methodology for establishing populations of this insect on water hyacinth can be determined. Once populations are well established, the purpose will shift towards determining the vagility (ability to disseminate) of this moth and its efficacy in controlling the plant.

Approach

Following clearance for the release of this South American species, pupae were obtained from the Gainesville U. S. Department of Agriculture quarantine facility. These were allowed to emerge as adults, mate, and oviposit. After the first instar larvae eclosed, they were placed in screen cages on waterhyacinth plants in a greenhouse. From an initial 2093 larvae, a substantial self-perpetuating greenhouse colony was obtained within three months. Infested plants were removed periodically and transplanted to three preselected field sites in south Florida. These sites are all at ca. 26° N latitude and equally spaced across the state. The first releases were made 1 June 1978 and releases are still continually being made. These releases are being continually monitored for signs of establishment and spread. The ultimate goal is to establish several populations in an east-west band across the southern part of Florida. Vagility will be estimated by monitoring for the presence of the insect at check-points away from this band. Efficacy will be evaluated based upon changes in various characteristics of the plants following the establishment of the insect.

Current Status

To date, 1727 infested plants, 37 adult insects, and ca. 600 first instar larvae have been released. Establishment was verified at one site which, unfortunately, was treated with herbicides. There is now reason to believe that the insects have established at an alternate site. Overall, however, it is still too soon to assess the success or failure of these releases.

Significant Accomplishments

Procedures for developing, handling, and maintaining a laboratory colony of S. albiguttalis have been perfected. At least one field population has been established and possibly two others, as well.

Project B. Domestic survey of insects on Hydrilla verticillata and Myriophyllum spicatum.

Objective

The objective of this survey is to (a) provide a quantified list of the insects associated with these two weeks, and (b) determine which of these insects damage these plants and, if possible, to what extent.

Approach

The project was initiated in July with the hiring of the entomologist in charge. Samples of hydrilla from 31 locations in 14 Florida counties have been examined. Insects and other organisms are removed from samples of the weed during microscopic examination. Samples of watermilfoil from 10 different locations in New York, Florida, and Georgia have been examined.

Current Status

Preliminary analysis of these early collections indicates that, in Florida, hydrilla is eaten mainly by various species of snails (Gastropoda), the larvae of several species of caddisflies (Trichoptera), the aquatic larvae of the moth Parapoynx diminutalis (Lepidoptera: Pyralidae), and by at least five species of midge larvae (Diptera: Chironomidae). However, only the snails and the moth larvae, P. diminutalis, appear to cause any noteworthy damage to hydrilla. The initial collections of organisms on milfoil indicate that it is fed upon by various species of snails (Gastropoda), by the larvae of several species of caddisflies (Trichoptera), the aquatic larvae of the moth, Acentropus niveus (Lepidoptera: Pryalidae), a tiny weevil (Coloptera: Curculionidae), and several species of midge larvae (Diptera: Chironomidae). As with hydrilla, the main damage to milfoil appears to be due to snails and a moth larvae, in this case A. niveus. In addition, a small weevil collected at Crystal River, Florida, feeds on the flowers and a similar weevil is known from California.

BIOLOGICAL CONTROL

Principal Investigator: Gary Buckingham

R/A 12-14-7001-995

Objective

The main objective of this research is to obtain insects that are potential candidates for the bilogical control of aquatic weeds, to study their biology and morphology, and to evaluate their host specificity under controlled conditions. The secondary objective is to aid in the development of technology packages for utilization of insects and other biological control agents by agencies having responsiblity and resources for control operations.

Approach

The studies will concentrate on two submersed aquatic weeds, Eurasian watermilfoil (*Myriophyllum spicatum* L.) and hydrilla (*Hydrilla verticillata* Royle). Insects in the United States that are considered potential candidates will be tested in the beginning until the foreign survey program has progressed sufficiently to provide candidates. The relatively standardized procedures which have been developed for host specificity tests will be followed in order to clear the insects for introduction as quickly as possible. The best available candidates will be tested first, but the testing may need to be reoriented if candidates that are even more promising are found. A complex of control agents is desired rather than relying on a single agent. As the testing nears completion for apparently acceptable candidates, methods for shipping and laboratory colonization will be developed and a manual will be prepared in order to aid those people making release and evaluation studies.

Current Status

Literature surveys indicated that two U. S. insects, which have probably been accidently introducted from Europe, might have potential for biological control of Eurasian watermilfoil. One of these species, *Litodactylus leucogaster* (Marsh.) (=*Phytobius griseomicans* Schwarz) is

a small weevil which feeds upon the emersed flowers. Adults were purchased from a California collector, Robert Pemberton, and a laboratory colony was established. Two generations have now been reared, and the biology has been studied. The female eats part of an ovary and places the egg into the cavity. The neonate larva feeds in the buds and flowers and the older larvae feed on flowers, stems, and seeds. The mature larva eats part of the stem just below the water's surface and forms a brown cocoon which fills with air from the stem. The adults, which are able to spend long periods underwater, feed on the submersed stems, but feed primarily on the flower stalks. This feeding destroys flowers and seeds both directly and indirectly by cutting the stalk. There are probably two generations in the field. The autumn generation adults hibernate in plant debris on shore. At 24°C constant laboratory temperatures the durations of the various stages are: egg, 3 to 4 days; larva, 8 to 10 days; pupa, 5 to 8 days. Limited host-specificity tests indicate that both the adults and larvae will have a narrow feeding range. The adults fed moderately on smartweed (Polygonum) flowers and on leaves of parrot-feather (Myriophyllum brasiliense) and mermaid weeds (Proserpinaca). The petals of a few land plants were also eaten. Further observations on the biology and the host specificity are planned. The potential value of this species in a control program will probably depend upon the importance of seeds in the population dynamics of Eurasian watermilfoil and upon whether any effective natural enemies of this species already occur in the United States. The second species being studied is a small nymphalid moth, Acentropus niveus (Olivier). Larvae were collected in the St. Lawrence River near Massena, New York, in both June and September. The biology has already been studied extensively by other researchers. Attempts at laboratory colonization have not yet been successful because males and females have not emerged together. Females deposit their eggs in batches on the submerged vegetation and the neonate larvae tunnel into the stems. Older larvae feed externally on the leaves. When not feeding they hide in loosely formed shelters of leaf fragments. A hard cocoon is formed in a cavity on the stem and it is filled with air from the stem. The short-winged,

flightless female mates at the surface. She lives only one day. A normally winged female also occurs, but has not yet been found in the New York population. Older larvae fed on a variety of plants, including Potamogeton and hydrilla, in the host-specificity tests; they have also been collected on several species in nature. It is not known, however, whether a complete generation can be made on these plants. Attempts to determine this will be made.

Significant Accomplishments

The most significant accomplishment thus far is the laboratory colonization and the determination of the biology of L. leucogaster. It appears from the literature search that no detailed biologies have been reported for an aquatic ceutorhynchine weevil in the United States.

AQUATIC SITE SURVEY FOR PRESENCE OF BIOLOGICAL CONTROL AGENTS IN WATERHYACINTH AT THIRTY LOCATIONS IN LOUISIANA

Principal Investigator: Robert Barry
Associate Investigator: J. A. Foret

Modification of Contract No. DACW39-74-C-0074

AD-A077 528 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS F/G 6/6
PROCEEDINGS OF THE RESEARCH PLANNING CONFERENCE ON THE AQUATIC --ETC(U)
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Objectives

The objectives for this research effort are outlined as follows:

a. To establish as part of the baseline data effort for the large-scale operations management tests on insect and plant pathogens in Louisiana a comprehensive list of insects and diseases associated with waterhyacinth (Eichhornia crassipes (Mart.) Solms.)

b. To evaluate visually the potential effectiveness of the biological agents observed at each site surveyed.

c. To collect data on waterhyacinth vigor, stage of maturity, and abundance at each site.

d. To collect data on water movement, depth, pH, temperature (surface and bottom), and dissolved solids.

Approach

Fifteen sites north of Interstate 10 and a similar number of sites south of this highway were selected for the survey. Each site was surveyed twice during the 1978 growing season. The first site investigation was conducted during the period of May 23 through May 31, and the last investigation of these sites was made during the period of August 17 through August 23. The following information was collected at each site:

a. Kind of insects and extent of feeding on waterhyacinth.

b. Plant disease symptoms present (photographs were made and samples of infected plants were collected for pathogen identification).

c. Growth stage and vigor of waterhyacinth.

d. Water pH, dissolved solids, and water temperature.

e. Direction of water flow, if moving.

Current Status

Each of 30 sites covering the State of Louisiana were evaluated in May and again in August. Samples of diseased waterhyacinth were taken for identification of causal agents; this work is currently in progress. Data on insects, water temperature, dissolved solids, streamflow, abundance, vigor, and stage of waterhyacinth growth are presently being compiled into tabular form for a final report.

Significant Accomplishments

Evidence of Neochetina was found at many sites surveyed. Damage induced by this insect ranged from slight to heavy. Arzama, Orthogalumna, and grasshopper feeding was also recorded and found to be light to moderate at several sites.

Plants infected with pathogens were observed at several locations. Samples are being cultured for laboratory identification of pathogens at this time.

Several sites surveyed offer potential for large-scale testing of biological agents for waterhyacinth control. Many sites did not develop a significant growth of waterhyacinth or were sprayed with herbicide and offer no potential for such testing.

BIOCONTROL OF WATERHYACINTH THROUGH MANIPULATIVE AUGMENTATION OF *ARZAMA DENSA*

Principal Investigator: P. C. Quimby, Jr.

A/N WESRF-79-83

Objectives

The objective of this research is to test the effects of various environmental and procedural conditions for mass-rearing techniques in order to develop the most efficient and economical method of producing large numbers of larvae of the native moth Arzama densa. This moth is to be used in subsequent experiments designed to test this insect's efficacy during manipulative augmentations for biocontrol of waterhyacinth.

Approach

This phase of the research consists of several subexperiments essential to the development of an effective rearing procedure.

Source

Larvae collected in nature in south Louisiana are maintained on waterhyacinth plants caged in the greenhouse at the Southern Weed Science Laboratory. Adults collected from this colony are subjected to various types of cages as part of the search for optimum mating/oviposition conditions.

Diet

The sugarcane borer diet (as used previously by Louisiana State University researchers for Arzama densa is modified in various ways to improve its acceptability and suitability for early as well as late instar larvae.

Conditions

Physical conditions (containers, cages, temperatures, lighting, densities of insects, etc.) are to be varied so that optimum rearing conditions will be discovered.

Current Status

To date, Arzama densa larvae have been collected twice (in November 1977 and March 1978) at Venice, Louisiana. Moths have been

on waterhyacinth in cages in an air-conditioned greenhouse set at 80/70^{o}F day/night temperature. We have gone from "egg to egg" twice by reinfesting plants from moths reared on the greenhouse plants. Late instar larvae have been reared to adults on a modification of the sugarcane borer diet used previously by Louisiana State University researchers. Further diet modifications are being tested and extracts of waterhyacinth added to the sugarcane borer diet have produced marked improvement.

A portion ($19,000) of the funding received was used to develop a specific cooperative agreement with Dr. D. L. Shankland, Professor and Head of the Department of Entomology, Mississippi State University. Dr. Shankland has hired Dr. R. G. Baer, a recent graduate of Virginia Polytechnic Institute and State University, in a postdoctorate appointment to work specifically on the Arzama project. Dr. Baer reported for work at the Southern Weed Science Laboratory October 1, 1978.

Significant Accomplishments

Funding for this project was not received until April 1978, and insufficient time has lapsed to produce any real significant accomplishments in this particular research problem. Several minor findings have developed, primarily as a result of problems encountered:

a. The Arzama densa larvae will not complete their development when overcrowded, even if fresh plant material is furnished periodically. We find that only 10 to 15 larvae can be successfully reared in a 1-m^{3} cage. This is simple evidence of the tremendous potential this insect has for damaging waterhyacinth.

b. We found that many of the larvae we attempted to raise on diet would develop into pupae with short wings, and about half of them would die in the pupal stage. This problem was somewhat alleviated when we changed the larvae to fresh diet at 2-week intervals; the addition of a hot-water extract of waterhyacinth to the diet was even more beneficial.

c. One problem we encountered was a periodic outbreak of spotted spidermites on our waterhyacinth plants. We found that the mites can be controlled with a miticide with apparent little damage to *Arzama densa* larvae. More testing will be required on this point.

d. We have found that the moths prefer to lay their eggs on screen when caged. Therefore, we are successfully using a cage with removable screens from which eggs can be easily recovered.

We recently requested and received consultative guidance on this research problem from Dr. L. B. Brattsten, Department of Biochemistry and Ecology, University of Tennessee, Knoxville, Tenn. Dr. Brattsten suggested that we needed to increase the linolenic acid content of the diet and also to make it more moist. We are in the process of trying her suggestions at the present time.

The high mortality (ca. 50 percent) we have observed in our procedures has been very disappointing. We are hopeful that with less crowding on plant materials and with diet improvement, we can soon begin to achieve significant progress in the rearing program. We are now in the process of doubling our cage space.

BIOLOGICAL CONTROL OF AQUATIC WEEDS
WITH PLANT PATHOGENS

Principal Investigators: T. E. Freeman
R. Charudattan
K. E. Conway

Contract No. DACW39-76-C-0097

Objectives

The objectives of this study are to search for, evaluate, and ultimately utilize plant pathogens in a biological control program for water weeds. Plant pathogens have several characteristics that make them desirable biocontrol agents, but surprisingly they have been little studied for this purpose, especially in the aquatic environment. Therefore, initial studies in this program were designed to form a foundation for future work leading to a practical application of the results. We are now entering this latter phase.

Approach

Target weed species are: alligatorweed (*Alternanthera philoxeroides* (Mart.) Griseb), Eurasian watermilfoil (*Myriophyllum spicatum* L.), hydrilla (*Hydrilla verticillata* (L. fil.) Royle), and waterhyacinth (*Eichhornia crassipes* (Mart.) Solms-Laub.). The latter two are the most noxious. It has been estimated that $15 to $20 million are spent annually in Florida alone in control efforts for these plants. For this reason the bulk of our work is directed towards waterhyacinth and hydrilla.

There are six pathogens that have been found affecting waterhyacinth that show biocontrol potential against waterhyacinth; they are: *Acremonium zonatum* (Sawada) Gams, *Bipolaris stenospila* Drechs., *Cercospora piaropi* Tharp, *C. Rodmanii* Conway, *Rhizoctonia* spp., and *Uredeo eichhorniae* Fragoso and Cifferri. All of these except *B. stenospila* and *U. eichhorniae* are native to Florida.

Current Status

Presently, *C. rodmanii* appears to have the greatest biocontrol potential of those being studies. It causes small punctate spots on the leaves and petioles of affected plants. Severely diseased plants

become chlorotic with spindly petioles. A root rot develops and plants eventually die and sink below the water surface. This fungus was originally isolated by Dr. Conway from plants in Rodman Reservoir in Florida. It is now believed to have been the cause of a severe decline of waterhyacinths in that body of water in 1971, and to a lesser extent in 1972 and 1973. It reoccurred in 1976 and 1977 and caused severe damage. This latest outbreak was augmented by spraying of the fungus onto plants in restricted areas of the reservoir. The fungus was grown in the laboratory on a synthetic medium, mascerated in a blender, diluted with water, and sprayed onto the plants with a conventional power sprayer. Infection took place within two weeks and the disease spread rapidly from the inoculation site to adjacent areas of plants.

Successful inoculations of plants with C. rodmanii has also been conducted in other areas of Florida (three locations) and Louisiana (one location). Thus far, our tests have been relatively small but larger scale tests are planned at more locations during 1978 and 1979. Host range tests indicate that the fungus is highly host specific for waterhyacinths. The results thus far obtained with C. rodmanii are very promising.

Significant Accomplishments

So much so that Abbott Laboratories is researching the conversion of the fungus into a product form and the University of Florida is seeking a patent on the fungus. The fungus has been shown to spread from study areas into adjoining bodies of water where early evidence indicates that its population is reaching a level where control of waterhyacinth is beginning to take place. The fungus is now found at over a dozen widely scattered areas in Florida where only a few years ago it was found in only one. At least part of the spread has been as a result of our efforts but some, such as in the St. Johns River, have no doubt resulted from natural spread from the original origin of the disease in Rodman Reservoir.

Acremonium zonatum has also undergone extensive testing. Its potential appears to be in the area of integrated control with other biotic agents such as insects and other fungi. A resistance mechanism of the waterhyacinth to this fungus was defined and its operation elucidated by R. D. Martyn for his Ph. D. dissertation while working on this project. His findings are extremely important in planning of biocontrol programs with A. zonatum. The disease resistant mechanism revolving around the phenol content and polyphenoloxidase activity in the plant was defined. This mechanism probably accounts for the fact that only a few serious diseases affect this noxious plant. Efforts are under way to find methods of shunting around this disease resistant mechanism.

A pathogen of hydrilla with biocontrol potential has recently been found. It is Fusarium roseum 'Culmorum' isolated by Dr. Charudattan from Stratiodes sp. from Holland. Domestic isolates of this fungus have also been obtained and are being researched for their potential as biocontrols of hydrilla. In addition, other species of fungi isolated from dying hydrilla have been and are still being tested for their biocontrol potential. We will continue our studies of these hydrilla pathogens.

In summary, considerable progress has been accomplished toward attaining our goal of the utilization of plant pathogens in the biological control of water weeds. We are especially encouraged by the successes achieved with C. rodmanii. In addition to the Corps' support, that of the Office of Water Resources Research and Technology, Florida Department of Natural Resources, and the Center for Environmental Programs of the Institute of Food and Agricultural Sciences of the University of Florida has made this progress possible. We anticipate that our continued research in this area will ultimately lead to the successful utilization of plant pathogens in biological control programs for aquatic weeds.

BIOLOGICAL CONTROL OF NOXIOUS AQUATIC PLANTS
IN PUERTO RICO

Principal Investigator: Leonce Bonnefil

Contract No. DACW39-79-C-2447

Objectives

The main objectives of our present Corps-sponsored research program are:

a. To identify and investigate the aquatic plant complex of of Puerto Rican waterways which interferes with fishing, causes water loss, impedes normal dam operation, imparts odor and taste to drinking water, and possibly encourages insect and nematode-borne diseases.

b. To promote biological control as a support to mechanical removal of water plants which is of limited use in Puerto Rico or to chemical control which may be circumscribed to certain parts of the Island water bodies.

c. To preside at the release in the wild of the waterhyacinth weevil and monitor the efficiency of the field populations.

It is hoped that this program may be broadened to include studies related namely to new bioagents and to insect-host plant relationships.

Approach

At the time the Corps-funded program got under way, the white amur had already been introduced through private initiative in the artificial ponds (water hazards) of the golf courses of Dorado Beach and Cerromar Beach Hotels, at Dorado, Puerto Rico.

The introduction of the herbivorous fish was done without definite plan and no precise records were kept of the releases which were made at various times and at different rates.

To really assess the degree of success of the introduction and identify possible adverse factors, some baseline information had to be worked out related namely to pond bottom profile, water sources and relative abundance, sources of weed infestation, etc. The white amur also had to be inventoried and redistributed to avoid overstocking and understocking, both of which create adverse effects.

Concurrently, studies were conducted related to the possible negative action of the herbivorous fish on the ponds' microflora, the competitive effect of the carp on local fish species, and the palatibility of waterhyacinth to the fish.

More directly aimed at the control of waterhyacinth was the introduction of the waterhyacinth weevil Neochetina eichhorniae. The insect was introduced and tested against local species of plants considered to be of ecological or economic significance. Most probably, Sameodes will also be introduced to be used eventually in combination with Neochetina. There is no doubt that the control of certain weeds in Puerto Rico will be largely dependent on biological control, mechanical and chemical control methods being either costly or of limited use.

Due to the steep topography and the marked fluctuations in water abundance, weevil populations will probably vary a great deal, and unusual dynamic manifestations in the biocontrol agent populations are foreseen. It will be necessary to study phenomena such as low level of stress allowing the recovery of the aquatic plants, movements of the weevils due to the washing downstream of the plant masses, fluctuations in insect populations due to changes in the aquatic plants relative abundance, etc.

Current Status

The project with white amur is now at the state of introducing more fish, but under better conditions. Releasing the fish in other bodies of water where coontail, filamentous algae, and duckweed are a problem is being considered. White amur may not be considered, however, as a major control for waterhyacinth. Poaching will be a serious limitation to the success of white amur as a biocontrol agent.

A considerable amount of research is being done with Neochetina in the laboratory and the greenhouse. Research conditions are fair and are being improved.

Part of our research staff's time is being diverted toward the running of bioassays with 2,4-D in preparation of a field trial with that herbicide. It is yet possible that chemical control will play a role in weed control in Puerto Rico alone or in association with biological control.

Significant Accomplishments

The major accomplishment of the Corps-funded research program in Puerto Rico has been in establishing biological control as a highly useful aquatic plant control strategy. In less than two years all agencies and private individuals on the Island have come to recognize that it can be of significance and must be accounted for in any planned aquatic plant control program.

On the basis of research, Neochetina is being considered for release in the wild in Puerto Rico. The release sites will be monitored for a period to be determined later. Local scientists are advocating other insects besides Neochetina.

More sophisticated studies have been planned in relation with the bionomics of Neochetina and the dynamics of its populations in the physical context of the Island.

It has been shown beyond any doubt in a first bioassay that 2,4-D has no adverse effect on an authorized indicator organism. This may allow the use of the herbicide at least in certain situations in Puerto Rico as permitted by the specific insular conditions of that country.

MONITORING OF EURASIAN WATERMILFOIL ON ROBERT S. KERR RESERVOIR

Principal Investigator: Arthur R. Benton, Jr.

Contract No. DACW39-77-C-0068

Objectives

This project is a continuation of a similar Corps-sponsored study initiated in 1977 for the purposes of (a) testing the use of seasonal color infrared aerial photography for whole-lake monotoring of the growth and spread of Eurasian watermilfoil as well as for determining the effectiveness of herbicide applications, and (b) providing possible new insights into the socioeconomic impacts of submersed plant infestations. The first year's work having been completed, the 1978 follow-on research represents a refinement of the 1978 work.

Present objectives include:

a. Provision of seasonal aerial photographic monitoring of aquatic plant infestations on Robert S. Kerr Reservoir during 1978.

b. Documentation, on 1:24,000-scale maps, of the lake's seasonal plant coverage and of the impact of herbicide applications.

c. Correlation of plant growth variations throughout the lake with differences in environmental parameters.

d. Expansion of the economic studies completed in 1977.

Approach

Monitoring and mapping

As before, the primary field methodology combines seasonally acquired photography with near-concurrent ground truth for monitoring the growth, spread, and reaction to herbicides of the aquatic vegetation on a major reservoir. Ground-verified photographs from the several seasonal overflights are then analyzed to determine seasonal differences and to correlate those differences with spatial and temporal changes in the lake's environmental conditions and in the human activities occurring there. Seasonal maps, at 1:24,000 scale, are compiled to provide cartographic documentation of plant community boundaries at discrete seasonal points in time.

Growth pattern analyses

Basic data comes from seasonal observation of the several types of plant communities around the lake. From analysis of sequential synoptic data, determinations are made as to where spread rates are highest and where they are lowest--the point being to gain insight into the reason for those differences that occur. Aerial photography is particularly helpful in determining the manner in which new outbreaks evolve from older infestations.

Economic factors

The existence of noxious aquatic plant infestations of even minimal size results in a variety of social and economic impacts. In this portion of the study, economic analyses are made concerning which impacts may be measured quantitatively and which are only qualitative. Specific dollar-per-acre impacts may then be determined, where feasible, and a framework established for assessment of the costs-versus-benefits from plant control efforts on given infested lakes.

Current Status

All of the objectives set for the first-year work (1977) have been achieved. The final report has been completed: this includes the narrative report, the seasonal maps, and copies of all of the aerial photographic imagery taken during 1977. Second-year fieldwork is half done as of this writing; the remainder is scheduled for late October and late December. The first of four interim reports of the 1978 research is nearly complete. Work on the entire project may be considered about 30 percent complete as of 10 October 1978.

A somehat similar project is being carried out concurrently at Pat Mayse Reservoir in northern Texas. This study--being undertaken for the Tulsa District Office--is for the purpose of mapping the occurrence of aquatic plants on that lake. Fieldwork is 50 percent done and the base map is now about 80 percent compiled.

Significant Accomplishments

Results of the 1977 monitoring study

It was determined that R. S. Kerr Reservoir is presently a one-plant lake, with watermilfoil dominant but with scattered, transient patches of American lotus, coontail, and pondweed. The watermilfoil winters over, with spring growth initiating from the previous year's boundaries. Seasonal growth tends to be slow and steady during the fairly long season. The R. S. Kerr infestation underwent remission in a few areas during the height of the growing season, although some of the apparent dieback resulted from unauthorized herbicide applications by parties unknown. Spread of watermilfoil seems to be quite limited by diminution of light, the beds expanding into greater depths where the water is clear than where it is turbid.

The photographic method worked well for monitoring of spread and detection of new infestations, ease of detection being a function of photographic scale. The effectiveness of herbicide applications was fairly easy to evaluate with sequential photography. It would appear that Tulsa District personnel, with brief training, could run an in-house monitoring program at relatively modest cost.

Results of 1977 socioeconomic study

Of the social factors, public health was not found to be quantifiable at this time. Public safety--meaning reduction of the incidence of drowning deaths via aquatic plant control--was assigned a dollar benefit per acre.

Of the economic factors, recreation, irrigation, and property value were found to be quantifiable at this time and defensible dollar-per-acre values have been assigned. Restoration of recreational activity, contrary to what has been written previously about this benefit factor, seems to be an exponential function rather than a linear one. The rationale for selection of exponential constants is presented in the final report.

Such economic factors as navigation, water supply, flood control, hydroelectric power generation, and thermal power plant cooling are all subject to significant long-term economic impacts from submersed aquatic plant infestations--the result of accelerated eutrophication--however, these impacts are not now quantifiable because the quantitative effects of aquatic plants on eutrophication rates are not yet known.

Results to date of 1978 monitoring study

Available imagery to date includes the flights of June and August 1978. In spite of precautions taken to obtain photography during clear-water periods, the lake was rather turbid on both flight dates. Despite reduced visibility into the water column, a few early results might now be ventured.

Observation of the final imagery of the 1977 season, inclusive of an early spring 1978 flight, shows the considerable extent to which Eurasian watermilfoil overwinters. The plants were at their winter best in the waters immediately downstream along the Illinois River from Tenkiller Dam. The water here, besides being clear, is relatively cold in summer and warm in winter.

Although watermilfoil overwinters in climatic areas where hydrilla would totally senesce, watermilfoil is seen to grow and spread much more slowly than hydrilla. American lotus, which occurs in substantial amounts in R. S. Kerr Reservoir, grows and spreads quite rapidly but its period of maturity is brief.

A fair amount of 1978 early season growth and spread beyond 1978 boundaries has been observed in some milfoil-infested areas; however, the growth rate seems to have been substantially inhibited by abnormally high turbidity.

Results of the economic assessment study

The analytic methodology is still being evolved, pending sponsor feedback from results of the 1977 socioeconomic study.

AQUATIC MACROPHYTES OF LAKE CONWAY

Principal Investigator: Larry Nall

Contract No. DACW39-76-C-0083

Lake Conway in central Florida has been chosen by WES as the site of the "Large-Scale Operations Management Test of Use of the White Amur for Control of Problem Aquatic Plants." The Florida Department of Natural Resources, Bureau of Aquatic Plant Research and Control, has been contracted by the Corps to study the effects of the white amur on the aquatic plants in Lake Conway.

Objectives

The objectives are to monitor the vegetation until project termination. From this data we hope to determine the effect of the amur on the ecology of the aquatic plants. Of special interest is the effect on hydrilla, which is the target plant of the study, and the associated response of other species after its removal. We hope to measure the rate of removal of vegetation by the fish and its feeding preference for the various species.

Approach

To accomplish these goals we sample the lake using several methods. Each month approximately 200 plant biomass samples are taken at fixed points along transects. These samples are more sensitive to changes throughout the lake. Twice yearly 60 plant biomass samples are taken in a random manner in each of the lake's four major pools. These samples are more able to measure the exact amount of vegetation in the lake with a reliable estimate of error than are the transect samples, but is less sensitive to change. Sixteen homogeneous plots were established and are sampled monthly by divers. At these stations species composition, plant height, stem density, and internodal distances are measured. Maps of shoreline vegetation are drawn quarterly; however, rapid shoreline development has destroyed any chance of separating the effect of the amur from human influence. Also, a fluctuating water level greatly affects the marginal plants, further complicating the study.

Current Status

Presently, two full years of data collection have been completed. The first year's baseline data report has been published and is available. The second year's report on the first poststocking year is in preparation. Presently, plans are to continue monitoring the lake until after September 1980.

As expected no widespread effect of the amur has been detected; however, underwater observations have located many small areas which have been denuded by the amur. Fecal droppings at these sites offer definite proof of the amur's activity.

Two years of sampling have shown a general increase in the occurrence of all major species throughout most of the lake. Hydrilla is a major plant in two pools. In the south pool its biomass has been increasing gradually and in the west pool it increased rapidly during the first year and then maintained itself at the same level through the next year. Nitella's biomass has declined slightly in the south and middle pools, but is it still the dominant plant in all but the west pool.

Significant Accomplishments

Although the effect of the amur, which is the primary objective, has not yet been observed, several significant accomplishments have been made.

First, the prototype plant biomass sampler, designed specifically for this project, has completed two years of intensive use and has had few major breakdowns or design changes. When compared to a diver using a standard square, the sampler has proven to be much more consistent and faster, especially in dense vegetation.

Presently, three measurements of plant biomass (wet, spun, and dry) are used in the literature. All three of these measurements were taken during the first study year. Conversions between the measures were developed so that the results of this study could be

compared to others. Comparison of the three methods showed that wet weight was the most consistent, therefore, this measure was used in all reports and presentations.

Few scientific studies of plant biomass and production have been made, particularily in the South. The data already taken in this study should make a valuable contribution to the study of lake biology, especially when coupled with data collected by the other investigators.

BENTHIC INVERTEBRATE AND PLANKTON STUDY
OF LAKE CONWAY

Principal Investigator: Tom Crisman

Contract No. DACW39-76-C-0076

Objective

The objective of this research is to provide detailed quantitative data on the aquatic biota of Lake Conway, Florida, that may be used to determine the effect of grass carp introduction on the biological balance of the system.

Approach

A total of 13 littoral and limnetic stations were sampled monthly in the five pools of the Lake Conway system for chlorophyll, planktonic algae, and zooplankton. In addition, benthic macroinvertebrates were sampled bimonthly and periphytic algae quarterly.

Chlorophyll samples were collected in 0.5-ℓ dark-plastic bottles and stored on ice until complete analysis could be performed in the laboratory after extraction with acetone. Samples for planktonic algae were collected by means of a Kemmerer bottle (shallow areas) or a mechanical pump (deep areas) and preserved with 5 percent tetraborate-buffered formalin. In the laboratory, all algal counts were performed utilizing an inverted microscope, and at least 200 to 400 individuals were tabulated for each sample.

Zooplankton samples from each station represent a composite sample obtained by means of a vertical haul through the entire water column with #10 and #20 U. S. standard plankton nets. Samples were preserved with tetraborate-buffered formalin. In the laboratory, at least 200 individuals were identified for each sample utilizing a magnfication of 20 to 50 diameters. Benthic macroinvertebrates were collected bimonthly at 21 stations, with all samples collected in duplicate. Samples were obtained by means of a petite Ponar grab and sieved through a U. S. standard #30 sieve. The material so retained was fixed with a 5 percent formalin-rose bengal solution and returned to the laboratory for sorting and counting. In addition to taxonomic work, all samples were analyzed routinely for invertebrate biomass and diversity.

Current Status

Gathering of prestocking biological data began in April 1976 and continued until grass carp were introduced into Lake Conway during the fall of 1977, the official start of data collection for the poststocking period. All biological monitoring since that date is considered part of the poststocking data base. Because of a continuation of both sampling regime and sampling personnel, we shall have a strong data base for making detailed comparisons of prestocking and poststocking periods.

At present, it is premature to present a definitive picture of the influence of grass carp on the Lake Conway system because of the relatively short period that has elapsed since fish stocking. In general, chlorophyll levels following fish stocking display the same seasonal trends as before stocking, thus suggesting that productivity of the Conway system has not undergone a major transformation.

The algal flora continues to display the same yearly successional sequence observed prior to fish introduction where cyanophytes (blue-greens) and chlorophytes (greens) are codominants of the flora from early summer to late fall. This fact, coupled with the increased importance of cryptophytes and chrysophytes (diatoms), is indicative of the general mesotrophic conditions of the lake system. In general, algal population and chlorophyll peaks are coincident and occur during the warmest period of the year.

Zooplankton populations display peak abundance from late fall to late spring; a pattern roughly inverse to that of planktonic algal biomass. Copepods are clearly the dominant element in the zooplankton fauna of the south pool (least productive), but with increasing productivity, rotifers and cladocerans emerge as the dominant zooplankters. On a seasonal basis, cladoceran abundance in all pools declines during midsummer.

As with the other biotic components, benthic macroinvertebrates displayed similar seasonal patterns between prestocking and post-stocking years. Shallow water (<3 m), when compared to deep water (>3 m), stations continued to be characterized both by greater invertebrate density and diversity.

In summary, all of the biological parameters suggest that Lake Conway has not undergone a drastic alteration during the first year following introduction of the grass carp. It must be emphasized that one year may not be sufficient time to detect the long-term effects of grass carp introduction that are manifested in a time-lag response of the system.

Significant Accomplishments

One master's thesis and one Ph. D. dissertation dealing with the Lake Conway work will be completed by March 1979. The master's thesis represents a detailed analysis of the mechanisms controlling the diel vertical migration of zooplankton and is not only the first study of its kind in subtropical lakes, but may be the most significant contribution to this very complex theoretical problem in the last 10 years.

The Ph. D. dissertation was concerned partially with the relation of zooplankton communities to lake trophic state but dealt primarily with construction of nutrient and hydrologic budgets for the Lake Conway system. The value of these submodels for understanding baseline nutrient external loading and internal cycling for subsequent comparison with later budgets derived for the period following grass carp introduction cannot be overemphasized.

FISH, MAMMELS, AND WATERFOWL OF LAKE CONWAY

Principal Investigator: Scott Hardin

Contract No. DACW39-76-C-0081

Objective

The objective of this research was to determine any changes which occur in fish, waterfowl and wading bird and aquatic mammal populations after introduction of grass carp (*Ctenopharyngodon idella*).

Approach

Baseline data were gathered for approximately one year before grass carp were introduced. Data collected after stocking will be compared to that of the baseline period to assess any ecological effects associated with the fish. Parameters measured were:

Parameter	Method
Fish	
Standing crop	Block net
Shallow water fish populations	Wegener ring
	3.0-m seine
	6.1-m seine
Pelagic fish populations	Gill net
Deeper Littoral zone fish populations	Electrofishing
Condition factor (K_{tl})	Electrofishing
Length-weight	Electrofishing
Analysis of stomach contents	Electrofishing
Diversity indices	All (except block net)
Sport fishery	Creel census
Waterfowl	
Abundance and species composition	Direct count
Analysis of gizzard contents	Shotgun
Aquatic Mammals	
Florida water rat nest abundance	Direct count
Small mammal populations	Trapping

Current Status

Collection of the first year's poststocking data has been completed and is being summarized for analysis and comparison to the baseline period.

Significant Accomplishments

Block nets produced slightly higher biomass in 1977-78 than during the baseline year, but differences were not significant. There was no difference in the amount of sport fish harvested each year, but forage fish produced greater biomass in 1977-78 than the previous year.

No differences were observed in shallow water fish populations except in 6.1-m seine hauls in nonvegetated beach sites. Both the number of individuals and biomass per collection decreased significantly from the baseline period. Diversity indices were quite variable.

Gill nets yielded no significant differences between years in number of species, number of individuals, and biomass. Florida gar, largemouth bass, and gizzard shad were the dominant species captured.

Electrofishing samples in beach and vegetated areas produced less biomass this year than during the baseline period. The number of fish captured during 1977-78 was more variable than 1976-77. Although a greater number of species were collected during the baseline year, monthly variation rendered any differences nonsignificant.

Preliminary analysis of length-weight regressions for largemouth bass, bluegill, and chain pickerel showed little change from the baseline period. Bluegill taken from June-August 1978 were heavier for their length than those sampled during that quarter in 1977.

Unidentified fish was the major food item for largemouth bass during 1977-78. Crayfish (*Procambarus* sp.) and grass shrimp (*Palaemonetes paludosus*) were the most common invertebrates found in bass stomachs. This pattern was also observed in 1976-77.

Dipterans predominated in stomach contents of bluegill for 1977-78, with chironomid larvae the principal item. Crustacea were observed in 98 percent of bluegill examined, an increase from the baseline year. Other items with an increased frequency of occurrence from 1976-77 were amphipods (Hyallela azteca), ostracods, and Planorbidae (Gyraulus sp.).

Unidentified fish were the most common food organisms for chain pickerel. Brook silversides were the most frequently encountered species. Fewer fish species were taken in 1977-78 and average weight of stomach contents was less than in 1976-77. Crayfish and grass shrimp were major invertebrate organisms taken.

Grass carp have increased steadily in size, the largest specimen captured weighing 5030 g. Analysis of foregut contents revealed almost exclusively vegetable matter with nitella (Nitella furcata (megacarpa)) and Illinois pondweed (Potamogeton illinoensis) constituting the major species consumed.

American coot (Fulicaamericana) was the principal migratory waterfowl species on Lake Conway, with a lesser population of ring-necked ducks (Aythya collaris) during the colder months. Fewer birds were observed during 1977-78 than the previous year. Hydrilla leaves were found in 75 percent of gizzards from American coots; Illinois pondweed leaves and stems were also heavily utilized, occurring in 36 percent of coots examined. Ring-necked ducks fed mainly on seeds from Illinois pondweed and oogonia from nitella. Little animal food was taken.

Observations of nests of the Florida water rat (Neofiber alleni) indicated a mobile, variable population. Nest counts fluctuated with water level, with the animals apparently burrowing during dry periods. Pickerelweed (Pontederia cordata) and waterhyacinth (Eichhornia crassipes) were the principal plants used in house construction. Traps set in water rat nests had a 20 percent success rate, indicating several nests per individual.

WATER AND SEDIMENT QUALITY OF LAKE CONWAY

Principal Investigator: Ray Kaleel

Contract No. DACW39-76-C-0084

Objectives

The objectives of the water and sediment quality monitoring program are twofold:

a. Establish baseline conditions, i.e., concentrations of selected physical, chemical, and biological parameters characterizing water and sediment quality of Lake Conway before the introduction of the white amur. As part of the objectives, seasonal cyclic variations are documented as well as variability occurring because of other limnological considerations.

b. Continue the monitoring program after stocking of the white amur to detect changes in water and sediment quality from the baseline conditions in order to evaluate the impact of the fish.

Approach

To accomplish the objectives, 11 stations (Figure 1) are monitored in addition to the four permanent stations monitored by the Pollution Control Department. Also, depending on the depth of water encountered at a given station, samples are obtained from different levels, including near surface, middepth, and near bottom waters. Water samples from the stations are obtained monthly and are analyzed for the physical, chemical, and biological parameters (Table 1) selected to meet the objectives of the monitoring program. Similarly, samples of sediments and aquatic plants are collected and analyzed quarterly. Upon completion of the analysis, these data are forwarded to the Corps.

Current Status

Poststocking data are currently being analyzed and compared with baseline conditions. While the report on poststocking results is not complete, a cursory review of the data indicates that there have not been any gross changes in the water quality parameters. It is surmised that not enough time has elapsed since the introduction of the fish to

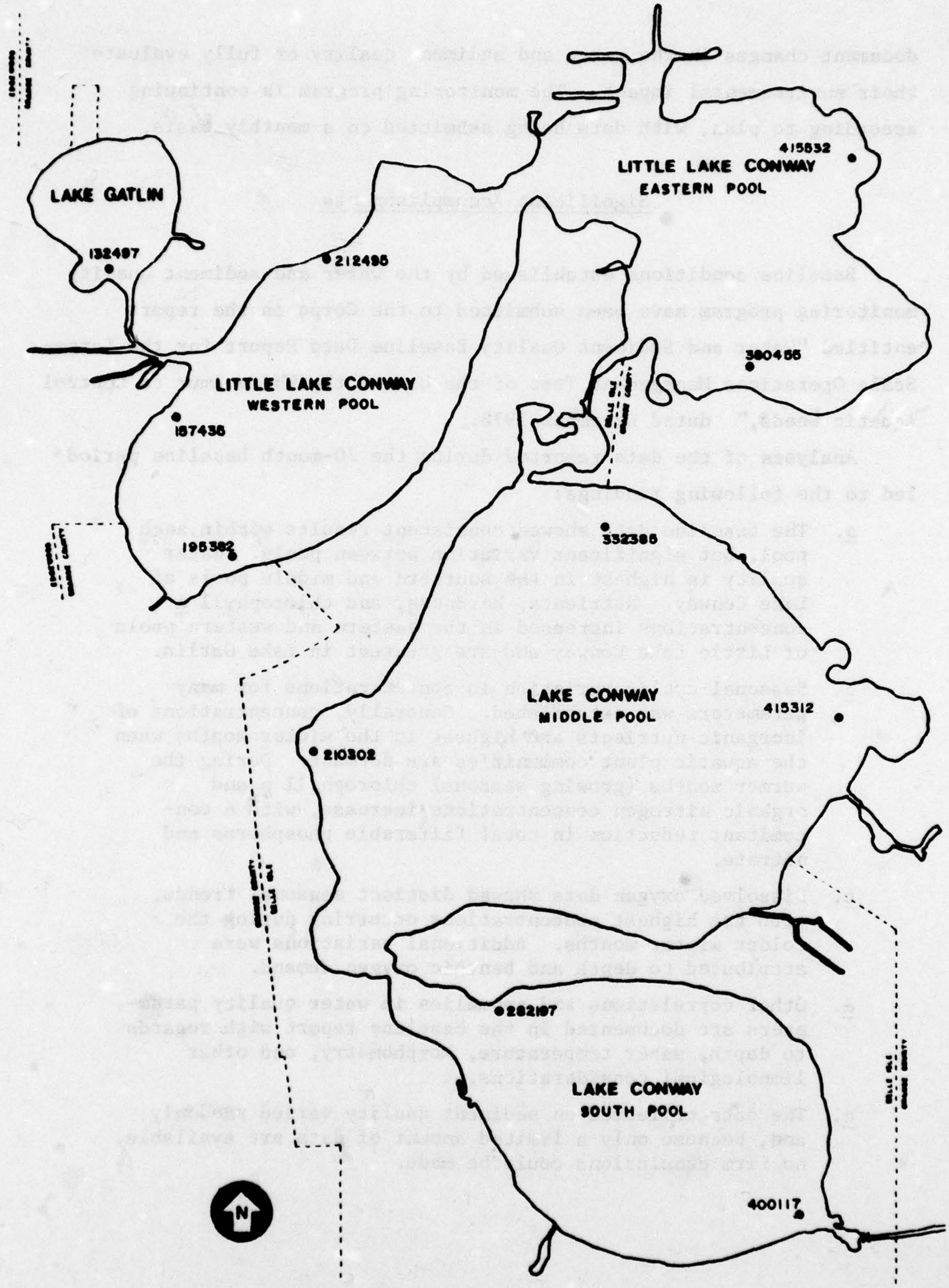

Figure A1. Sampling station locations

document changes in the water and sediment quality or fully evaluate their environmental impact. The monitoring program is continuing according to plan, with data being submitted on a monthly basis.

Significant Accomplishments

Baseline conditions established by the water and sediment quality monitoring program have been submitted to the Corps in the report entitled "Water and Sediment Quality Baseline Data Report for the Large-Scale Operations Management Test of the Use of the White Amur to Control Aquatic Weeds," dated November 1978.

Analyses of the data reported during the 20-month baseline period led to the following findings:

a. The baseline data showed consistent results within each pool, but significant variation between pools. Water quality is highest in the southern and middle pools of Lake Conway. Nutrients, hardness, and chlorophyll a concentrations increased in the eastern and western pools of Little Lake Conway and are greatest in Lake Gatlin.

b. Seasonal cyclic variation in concentrations for many parameters was established. Generally, concentrations of inorganic nutrients are highest in the winter months when the aquatic plant communities are dormant. During the warmer months (growing seasons) chlorophyll a and organic nitrogen concentrations increase, with a concomitant reduction in total filterable phosphorus and nitrate.

c. Dissolved oxygen data showed distinct seasonal trends, with the highest concentrations occurring during the colder winter months. Additional variations were attributed to depth and benthic oxygen demand.

d. Other correlations and anomalies in water quality parameters are documented in the baseline report with regards to depth, water temperature, morphometry, and other limnological considerations.

e. The data collected on sediment quality varied randomly and, because only a limited amount of data are available, no firm conclusions could be made.

f. While water quality is generally stable, some variations have occurred. An intense periphyton bloom occurred in the south pool, which resulted in nuisance conditions for lakefront property owners. This seasonal (late summer-fall) increase in periphyton growth was observed in the other major pools, but not to the extent where nuisance conditions were created. Data collected from the south pool during the time period showed higher concentrations of organic and ammonia nitrogen, which could have stimulated the bloom.

Table 1

Selected Water Quality Parameters*

Turbidity (FTU)	Orthophosphorus	Sodium
Total Phosphorus	Total Solids	Potassium
Organic Nitrogen	Volatile Suspended Solids	Magnesium
Nitrate Nitrogen	Fixed Suspended Solids	Chlorophyll a (Func)mg/m^3
Nitrite Nitrogen	Biochemical Oxygen Demand	Chlorophyll a (Non-Func)mg/m^3
Ammonia Nitrogen	Chemical Oxygen Demand	Carotenoids (mg/m^3)
Alkalinity	Copper	Chlorophyll a (mg/m^3)
Acidity	Iron	Chlorophyll b (mg/m^3)
Chlorides	Lead	Chlorophyll c (mg/m^3)
Hardness	Calcium	Productivity**

Monthly field measurements are taken at each sample depth for the following:

Depth (m)	Redox-potential (mV)
Secchi Disc (m)	Conductivity (μmhos/cm)
pH*	Dissolved Oxygen (mg/ℓ)
Water Temperature (^oC)	

Macrophyte† and Sediment Parameters

Chemical Oxygen Demand (mg/g)	Copper (μg/g)
Total Phosphorus (mg/g)	Iron (μg/g)
Total Nitrogen (mg/g)	Lead (μg/g)

* Concentrations of various parameters are reported in milligrams per litre unless specified otherwise.

** Initial, light and dark bottle dissolved oxygen data are reported for this parameter.

† Macrophyte analyses does not include iron and lead.

THE HERPETOFAUNA OF LAKE CONWAY

Principal Investigator: Roy McDiarmid

Contract No. DACW39-77-C-0047

Objectives

The objectives of this research program as part of the large-scale operations management test (LSOMT) of the white amur in Lake Conway, Florida, are:

a. Determine the species of amphibians and reptiles inhabiting the Lake Conway system.

b. Ascertain the density, distribution, seasonal occurrence, and habitat requirements of each species.

c. Establish quantitative baseline data for the more common or otherwise important species in the system including species density by pool, population density by habitat within and among pools, relative age (size) structure of species among pools, seasonal and annual movements and growth of individuals, food habits, reproductive activity, and related parameters as deemed feasible in the second year.

d. Quantitatively monitor any changes in species composition or in population parameters outlined above during the entire study.

e. Determine whether or not observed changes are the probable result, either directly or indirectly, of the white amur introduction.

Approach

During June and July of 1977 the total lake system was surveyed for habitat types. Based on this reconnaissance, one section of shoreline and one deepwater transect in each pool of the Lake Conway system were selected as permanent trapping and censusing sites. The sites chosen contain all major littoral and deepwater vegetation types with associated substrata and are representative of the habitats available to the native herpetofauna in the Lake Conway system.

As soon as the sites were selected and numbered markers placed at 10-m intervals along the shoreline, an intensive weekly sampling program was begun. This program includes the use of funnel traps set for 24 hrs at each marker throughout the sites and diurnal and nocturnal patrols

from a boat and shoreline along each habitat. All animals captured are identified, weighed, measured, sexed, permanently marked, and released at the capture site. Their capture point in recorded with reference to pool, habitat, marker, water depth, time, and behavior. The percent plant cover by species, water depth, and substratum at each trapping station for all shoreline sites are recorded quarterly. In addition to this routine sampling program, alligator censuses were conducted monthly and deepwater trapping done quarterly for the first year. After the first six months, the routine sampling was changed to a biweekly schedule so that all sites are sampled twice each month. This procedure will continue through the second year.

In addition to the live animal, mark, and recapture studies outlined above, monthly destructive samples from distant sites in similar habitats within the lake system are taken. These samples are returned to the laboratory at the University of South Florida for analyses of stomach contents and reproductive condition. These data are used to supplement the results obtained from the mark and recapture studies and facilitate the understanding of the potential impact of the white amur on the herpetofauna in Lake Conway.

Current Status

The first 12 months of the study are considered baseline for amphibians and reptiles in the system, even though the white amur was introduced only three months into the study.

The emerging picture of the Lake Conway herpetofauna is one of considerable complexity. During the first year 4378 specimens of 28 species of amphibians and reptiles were processed. This represents most of the species in the system and certainly includes all major components. Thus, the first objective has been realized and an understanding of the densities, distributions, and habitat requirements of the more common species is emerging. In general, species composition and herpetofaunal density in each pool reflects the availability of suitable habitat in the various pools.

Shoreline development has removed most of the littoral zone vegetation in all pools. In these disturbed areas many species have been extirpated or occur only in low densities. In undisturbed habitats, most common species exhibit specific habitat preferences which are correlated with vegetation type, water depth, substrata, and food availability. Many common species show distinct seasonal trends in reproductive activity, food preferences, and abundance. While recapture data for some species (especially turtles) indicate that they are highly mobile, other species exhibit site tenacity and territorial patterns of behavior.

As the sampling program continues through the second year, the patterns detected in the first year, particularly with reference to those population parameters mentioned in the third objective, are being expanded and confirmed. Later this year special emphasis will be placed on individual movements between habitats within pools. This information is critical to interpreting the population density estimates from the first year. As the study continues, modifications of the first year's sampling program will be made whenever and wherever needed. In the past six months, the sampling effort of necessity has been increased to provide additional data relative to habitat loss in the lake system. This problem of habitat loss continues to plague the research effort and increases the difficulty of detecting changes in species population parameters as the result of the white amur from any changes that are the result of habitat loss. However, current modifications of the sampling program are designed to distinguish between these two influences. To date, no detectable changes in amphibian and reptile species composition or population parameters have been noted as a result of the white amur.

RESPONSE OF AN ECOSYSTEM TO THE
INTRODUCTION OF WHITE AMUR

Principal Investigators: Katherine C. Ewel
Thomas D. Fontaine III

Contract No. DACW39-76-C-0019

Objectives

The objectives of this research were to:

a. Formulate a model of an aquatic ecosystem that represents the major flows of carbon and phosphorus in the Lake Conway ecosystem.

b. Use the model to predict the effects of white amur on the ecosystem.

c. Validate the model as information becomes available on actual effects.

d. Determine productivity of the lake before and after introduction of the white amur as a major parameter of the model.

Approach

A model was formulated based on relationships among organisms primarily as described in the literature. Plant populations in the model included phytoplankton, macrophytes (tubers were included as a separate unit) and epiphytic algae, and benthic algae. Animal populations included zooplankton, benthic invertebrates, planktivorous fish, young and adult primary predator fish, and young and adult top carnivore fish. Both particulate organic matter in the water column and bottom detritus were included in the model. Phosphorus levels in the epilimnion, interstitial water, and sediments were each modeled separately.

We measured primary productivity in the east pool of Lake Conway for one year in order to obtain values for the baseline model. Biomass levels provided by other contractors were used to calculate initial conditions for the model and to validate model behavior. An optimization program written by E. Blacher using phosphorus data supplied by the Orange County Pollution Control District reinforced assumptions that we had made on the significance of phosphorus secreted (25 to 30 percent of uptake) by aquatic macrophytes.

Current Status

The baseline model is stable during a six-year simulation. The following tabulation shows the minimum and maximum values reached during the third year of the simulation and the month in which these values were obtained (values are expressed in grams of carbon per square metre):

Unit	Minimum Level	Time	Maximum Level	Time
Phytoplankton	0.07	January	0.22	April
Macrophytes	56.96	January	97.09	May
Benthic algae	0.91	June	2.53	April
Zooplankton	0.00	February	1.98	June
Benthic invertebrates	0.45	February	1.98	May
Planktivorous fish	0.07	March	0.33	July
Adult 1^{o} predator fish	0.02	April	0.24	August
Adult top carnivore fish	0.13	May	0.49	November

Total gross primary productivity in the simulation is lowest in late summer and midwinter and highest in late spring. This pattern coincides with the pattern obtained for Lake Conway from the productivity measurements.

Phosphorus dynamics and trophic relationships among the animals are the two most sensitive areas in the model. The simulated pattern of change in water column phosphorus is out of phase during the summer with data reported by Orange County Pollution Control District. This may be due to an overestimation of the amount of phosphorus entering with runoff. Estimates of available phosphorus in the sediments and phosphorus uptake by macrophytes are needed to verify productivity limits. Zooplankton respond to small changes in dissolved phosphorus concentration (mediated by phytoplankton and macrophytes) and in turn have a significant effect on higher trophic levels because of their importance in the food chain.

The fish components of the model have the least validation from field studies of any of the components. We can use only data from block net samples, which are not set in enough places at one time to provide reliable estimates of biomass in the lake at that time. We, therefore, have no basis for validating the prestocking simulation, although annual changes that result from the simulation are consistent with literature values.

Introduction of the white amur was simulated by using the same size and density of fish actually put into the lake in September 1977. It was assumed that the white amur eats 95 percent of its body weight per day. The simulation predicts that fish surviving after one year would weigh an average of 13.5 lb (wet weight). Simulated macrophyte biomass reaches 85 percent of its prestocking maximum during the first summer after introduction, and 45 percent during the fifth summer after stocking.

Phytoplankton increase to 0.37 gC/m^2, nearly double their prestocking maximum, during the first summer after stocking. However, populations continually decline thereafter and reach a maximum of only 0.16 gC/m^2 during the fourth summer after stocking. Zooplankton biomass declines almost immediately and remains at very low levels for the rest of the simulation. Benthic algae and benthic invertebrates increase slightly. Herbivorous fish decline dramatically, but both primary predator and top carnivore fish increase significantly after initial declines when favored food items decreased in availability. Young of both groups decline, however, signaling an eventual decline in adult fish populations.

Significant Accomplishments

The magnitude and pattern of gross and net primary productivity and of respiration have been documented for a major southeastern lake ecosystem for the first time, to our knowledge.

Relationships between aquatic organisms and biogeochemical pathways have been elucidated sufficiently to produce a model that matches reasonably well with data that have been collected on major lake components.

The importance of internal nutrient loading to a southeastern lake ecosystem has been demonstrated with indirect evidence provided from simulation of the model.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

United States. Waterways Experiment Station, Vicksburg, Miss.

Proceedings, Research Planning Conference on the Aquatic Plant Control Program, 16-19 October 1978, Seattle, Washington. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1979.

155, 85 p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; A-79-7)

Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C.

1. Aquatic plant control -- Congresses. 2. Research planning -- Congresses. I. United States. Army. Corps of Engineers. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; A-79-7.

TA7.W34m no.A-79-7